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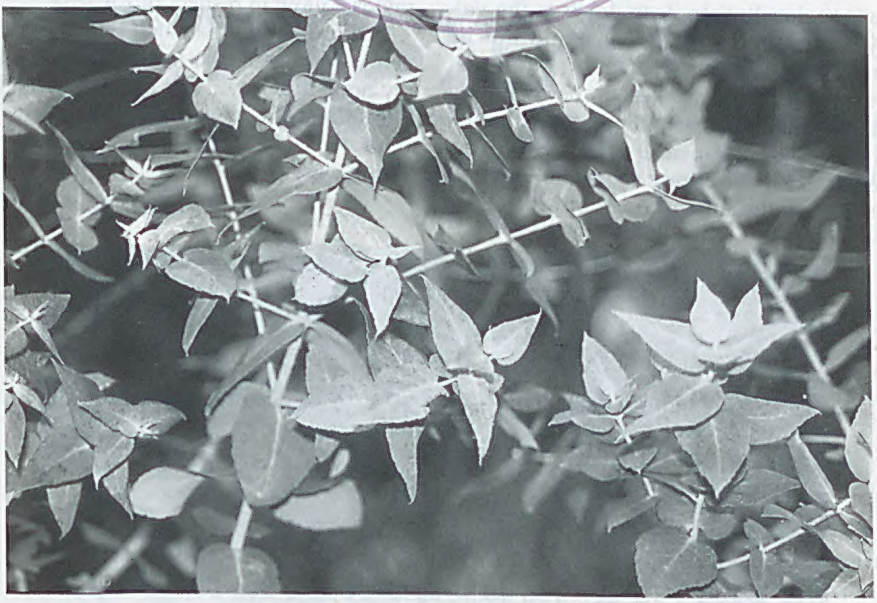

F.N.C.V.

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Australian Edelweiss at Mt Hotham: But for How Long?

The Australian Edelweiss *Ewartia nubigena* is an elusive creature, in line with its more famous and rather larger European cousin. It occurs mostly on exposed patches of shingle around the 1750 m level or above, appearing at first sight like a patch of grey moss or lichen, but revealing on closer inspection its tiny white daisy flowers.

Within the Mt Hotham Alpine Resort, which has recently been extended (by excision from the Alpine National Park) to accommodate new ski runs and facilities, there are, or have been, a few places where Edelweiss can be seen. On an inspection two years ago, the best of these was found just a short distance away from the Orchard Chair Lift Station, but this eluded me on a recent visit over New Year. Does it still exist? - I don't know. Another patch was previously seen deep down in the valley of Australia Drift, but could not be checked this time. However, the most accessible specimens were to be found, on this occasion (January 2001), as previously, growing **right at the very edge** of the 4WD track as it climbs from the Orchard Chair up to the summit ridge of Mt Loch. I gather from Jane Calder that it can be found elsewhere, such as on Mt McKay, as well as in the Kosciusko National Park at high altitude.

However, my dismay was considerable at discovering large drums of high voltage power cable laid out at intervals along the 4WD track, clearly about to be ripped into the track by a couple of D9s in tandem or whatever. This is evidently intended to be an alternative power supply to the Hotham Resort, connecting from the Gotcha Chair to the West Kiewa Power Station. It might appear to have come about as a result of opposition to a route via Dinner Plain to Omeo. However, it has the potential to make *Ewartia* very scarce indeed in Victoria, and any assurances that the area will be restored after the event are clearly rather hollow in respect of *Ewartia*.

It is a reminder that such things can happen very fast and be irreversible, and it is my hope that it will not be too late to save this unique alpine plant.

Alan Parkin
70 Allima Avenue,
Yallambie, Victoria 3085.

Fig. 1. The patch of Australian Edelweiss which was found two years ago near the Orchard Chair Lift Station, Mt Hotham and could not be found again this year. Most Edelweiss patches are much smaller than this.

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Volume 118 (1) 2001 February

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Index to Volume 117, 2000 is in the centre of this issue

Research Reports The Potential Impact of Freeways on Native Grassland, *by Nicholas S.G. Williams, Emma J. Leary, Kirsten M. Parris and Mark J. McDonnell* 4

Buxton Silver Gum Reserve: Using Geographic Information Systems to Investigate Historic Change in Site Integrity, *by Dianne Simmons, Robyn Adams and Chris Lewis* 16

Contribution Yarrow *Achillea millefolium* L.: a Weed Threat to the Flora of the Australian Alps, *by Frances Johnston and Catherine M. Pickering* 21

Naturalist Note Australian Edelweiss at Mt Hotham: But for How Long? *by Alan Parkin* 2

Book Reviews Celebrating Our Parks – Proceedings of the First Australian Symposium on Parks History, (Mount Buffalo, 16-19 April 1998), *edited by Elery Hamilton-Smith, reviewed by Deirdre Slattery* 25

Kosciuszko Alpine Flora, Second Edition, *by A.B. Costin, M. Gray, C.J. Totterdell and D.J. Wimbush, reviewed by R.J. Fletcher* 27

Pythons of Australia: a Natural History, *by Geordie Torr, illustrated by Eleanor Torr, reviewed by Nick Clemann* 30

Tribute John Paul Stewart, *by Noel Schleiger* 29

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Cover: The adult leaves of Buxton Gum *Eucalyptus crenulata* look like juvenile leaves. These mature leaves are an unusual characteristic of Buxton Gum. See article on p. 16. Photo: R. Adams.

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The Potential Impact of Freeways on Native Grassland

Nicholas S.G. Williams[1], Emma J. Leary[1], Kirsten M. Parris[1] and Mark J. McDonnell[1]

Abstract
Transportation planning typically considers only the direct impacts of road construction, such as loss of vegetation and wildlife habitat. However, the ecological impacts of major roads and freeways are not confined to the area immediately adjacent to the road. Recent international research has demonstrated the existence of a 'road effect zone' around major roads and freeways. In Melbourne many current and proposed freeways traverse areas of native grassland. This paper presents a review of the major ecological impacts of roads and how they may affect native grasslands using the proposed Hume Freeway F2 Link as a case study. The road effect zone of the Hume Freeway F2 Link route options are quantified and the impacts on the native grasslands of the Merri Creek Valley assessed.
(*The Victorian Naturalist* **118** (1), 2001, 4-15.)

Introduction

The past decade has seen many new freeways constructed in and around Melbourne. The Western Ring Road, City Link, Ringwood Bypass, Northern Ring Road and Eastern Freeway extension have been completed, the Deer Park bypass to link the Western Freeway and Western Ring Road is under construction and other proposed freeways are in the final planning stages. These include the Eastern Ring Road (Scoresby Freeway), a further extension of the Eastern Freeway through the Mullum Mullum Valley to Ringwood and the Hume Freeway F2 Link between Craigieburn and the Northern Ring Road. Most of these projects were subject to extensive environmental review through impact assessments, planning panel reviews and public hearings. Such studies tend to examine the direct impact of freeway construction on the biota. They typically assess the quality of the vegetation and occurrence of rare flora and fauna species along the proposed freeway alignment. However, recent international research has shown that the ecological impacts of freeways extend well beyond the area destroyed by the road and associated construction activities. The aim of this paper is to review the ecological impact of major roads on native grasslands and to discuss the concept of a 'road effect zone' using the proposed Hume Freeway F2 Link as a case study.

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Ecological Impact of Roads

More than 20 ecological effects of roads have been identified by scientists from around the world (Forman and Deblinger 2000). These include the dispersal of particulate and chemical pollutants, noise and introduced plants and animals (Forman 1995). Comprehensive reviews of the ecological effects of roads are provided by Bennett (1991), Forman (1995), Forman and Deblinger (1998), Spellerberg (1998) and Trombulak and Frissell (2000). Our intention here is to briefly discuss some of these effects to highlight the diverse range of impacts roads can have on the environment.

Sources of Pollution and Exotic Species

Vehicle traffic along roads contribute numerous chemicals to the environment including heavy metals, organic molecules (e.g. hydrocarbons), ozone and nutrients. De-icing salts are also a problem in colder climates (Trombulak and Frissell 2000). Water runoff from road surfaces may enhance growth of nearby vegetation or erode soils from roadsides and stream crossings. Most chemical transport occurs via stormwater runoff through and over the soil and from drainage into nearby water bodies. Pollutants may alter soil chemistry, be absorbed by plants and affect stream ecosystems (Forman and Alexander 1998). Roads also facilitate the dispersal of introduced plants and animals via three mechanisms: providing habitat by altering the natural conditions, making invasion more likely by stressing or removing native species and allowing easier movement by natural and human vectors (Trombulak and Frissell 2000).

Barrier and Fragmentation Effects

Forman (1995) considers that wide multi-lane highways, such as freeways, have the greatest ecological effect of all roads, as they remove more habitat and create more substantial barriers, effectively fragmenting the landscape and habitats they traverse. Landscape fragmentation with its associated loss and modification of habitat has been recognised as the greatest threat to biological diversity in Australia (Biological Diversity Advisory Committee 1992). Fragmentation not only reduces the quantity of habitat available for native plants and animals, but also reduces the suitability of the habitat that remains. Increased isolation of habitat patches may impede the movement of animals between patches and lead to local extinction of species (Haila *et al.* 1993). Fragmentation increases the ratio of edge to interior habitat, encouraging invasion by weeds (Scougall *et al.* 1993) and potentially increasing predation on birds and mammals (Andrén and Angelstram 1988; Burbidge and McKenzie 1989). Habitat fragmentation can also affect the reproductive success and probability of persistence of native plant species, by changing the plant's physical environment and its interactions with pollinators (Cunningham 2000).

Roads contribute to the fragmentation of habitat and the disruption of resident populations of plants and animals in a number of ways. A new road creates a physical barrier which splits patches of habitat into smaller, disjunct areas. Animals attempting to cross the road may be killed by collision with vehicles. In general, mortality increases with increasing traffic volumes (Rosen and Lowe 1994; Fahrig *et al.* 1995). The presence of a road may also modify an animal's behaviour. Species that are sensitive to noise and human disturbance will change their movement patterns and home ranges to avoid roads (Trombulak and Frissell 2000, and references therein). This avoidance of areas near roads further reduces the amount of habitat that is suitable for sensitive species in fragmented landscapes. The impacts of habitat fragmentation may be accelerated when local extinctions occur in important habitat patches as a result of increased mortality or a reduced probability of recolonisation associated with roads (Trombulak and Frissell 2000).

Noise

Research in the Netherlands has shown that noise from traffic severely disrupts the behaviour of grassland birds, causing them to move away from roads and to cease breeding. Depending on the species, roads with a traffic volume of 50,000 vehicles per day disturbed grassland birds up to 3530 m away (Reijnen *et al.* 1996; van der Zande *et al.* 1980). Reijnen *et al.* (1996) also found that populations of grassland birds were reduced by between 12% and 52% within 500 m of roads with a traffic volume of 50,000 vehicles per day. It is reasonable to assume that other animals will also be displaced by noise and disturbance created by roads.

The Existence of a Road Effect Zone

The ecological impacts of a freeway are not confined to the area immediately adjacent to the road. Ecologists throughout the world now recognise the existence of a 'road effect zone' (see *Conservation Biology* Vol. **14**, No. 1, 2000). Forman *et al.* (1995) describe a road effect zone as an area defined by the ecological effects extending from a road into the surrounding landscape. It is an area many times wider than the road surface and the roadside verge (Forman and Deblinger 2000).

The area impacted by the ecological effects of a road varies with the nature of the effect, quality of existing habitat, topography of the landscape and the prevailing wind direction. The road effect zone has convoluted boundaries and is highly asymmetric, due to the differential influences of environmental flows such as wind and water, and variation in habitats on opposite sides of the road (Forman and Deblinger 2000). Generally, it is larger down slope and downwind of the road, and in areas of higher quality vegetation or habitat (Forman 1999; Forman and Alexander 1998; Forman and Deblinger 1998). At points where a road crosses ecological conduits, such as streams, the road effect zone may extend much further outward. For example, particulate or heavy metal pollution from a road may extend for

many kilometres downstream of a bridge, but a much shorter distance upstream or into adjacent terrestrial ecosystems (Forman 1999).

Quantification of a Road Effect Zone: The Hume Freeway F2 Link

The Hume Freeway F2 Link, or F2 Freeway as it is also known, is a freeway planned to connect the Hume Freeway at Craigieburn to the Northern Ring Road at Thomastown. A reservation for the connection was initially created along the valley of the Merri Creek, a northern tributary of the Yarra River, in 1975. Since then studies have shown that the freeway reservation traverses the 400 ha Craigieburn Grasslands and the 70 ha Cooper Street Grasslands which are now recognised as being of National and State significance for biodiversity conservation respectively (Gibson *et al.* 1999). The Grasslands provide habitat for a number of Nationally and State listed endangered species. Significant flora include Curly Sedge *Carex tasmanica*, Mat Flax-lily *Dianella amoena* and Swollen Swamp Wallaby-grass *Amphibromus pithogastris* while the endangered fauna include the birds Plains–wanderer *Pedionomus torquatus*, and Swift Parrot *Lathamus discolor* and the Striped Legless Lizard *Delmar impar* (Muir *et al.* 1998). Both grasslands have also been listed on the Register of the National Estate under the *Australian Heritage Commission Act 1975* (Gibson *et al.* 1999).

Recognition of the significance of the grasslands and presence of endangered flora and fauna has led to a number of alternative routes being proposed by VicRoads (1998). Public submissions on these routes were evaluated by an advisory committee appointed by the State Government against a defined set of objectives whose final recommendation (Gibson *et al.* 1999) was VicRoads' route 5 (1998). In the process of preparing advice for the Minister of Planning, the Department of Infrastructure (DOI) reviewed the Planning Assessment (VicRoads 1998) and Advisory Committee Reports (Gibson *et al.* 1999). The DOI determined that it was not happy that any of the seven options evaluated by the advisory committee provided a 'satisfactory combination of transport, economic and environmental outcomes' and convened a working group that developed a further set of route options labelled X, Y and Z (Department of Infrastructure 2000).

The Hume Freeway Advisory Committee Report (Gibson *et al.* 1999) stated that there was no evidence produced to indicate that the potential impact of noise on fauna within the grasslands was an issue of any real concern (p. 190). This indicates that recent research from around the world into the ecological impact of roads and the road effect zone may not be well known to consultants, planners and government agencies. The Working Party report (Department of Infrastructure 2000) also failed to consider the extent of the road effect zones on the values of grassland in the Merri Creek Valley primarily considering the direct impacts of freeway construction. As a public submission on the Working Party report (Department of Infrastructure 2000), the Australian Research Centre for Urban Ecology conducted an analysis of the potential road effect zone of the existing Hume Highway and the proposed routes 5, X, Y and Z. The results of this research are presented below.

Methods

We quantified the area of grassland affected by the proposed Hume Freeway F2 Link using Geographic Information System (GIS) modelling. Maps of the route options and areas of native grassland were provided by the Merri Creek Management Committee. The amount of grassland in the road effect zones was calculated for each route option to estimate the total habitat affected by road noise and pollution. The distance used for the zones was based on an estimated 35,000-40,000 vehicles per day predicted by traffic modelling to use the Hume Freeway Link Options 1 to 5 (Gibson *et al.* 1999). The routes used to produce these projections have slightly different alignments to those of the current proposal; however, traffic modelling projections for routes X, Y, and Z were not available.

Forman and Deblinger (1998) describe the calculation of road effect zones based

on effect distances from research in the Netherlands on noise sensitive grassland birds (Reijnen *et al.* 1996). Forman and Deblinger (1998) used 810 m for 50,000 vehicles/day in natural ecosystems in urban areas. We were unable to obtain information on the effect of road noise on grassland birds in Australia so we have followed the example of Forman and Deblinger (1998) and used data from temperate grasslands in the Netherlands. However, we adopted a conservative 'road effect zone' of 750 m for each route option due to traffic volumes estimated to be less than 50,000 vehicles per day reported in the Dutch study. The Hume Highway was also given a road effect zone of 750 m when considered in combination with any of the Hume Freeway Link options. The road effect zone of an upgraded existing Hume Highway was estimated to be 1 km, as the projected traffic volume on an upgraded Hume Highway is estimated to be 64,000 vehicles per day (Gibson *et al.* 1999). The area of the road effect zone does not include the added effect of the upgrading of the east-west roads in the area, such as Cooper Street and Craigieburn Road East, to four lanes. This would further fragment the landscape and reduce the area of core habitat available for many species.

The road effect zone is more complex than simply affected and non-affected areas. There will be a decline in intensity of road effects with increasing distance from the road, and the distance and significance of the effects will vary depending on the organism examined. We used grassland birds to illustrate the potential area of grassland affected by the Hume Freeway F2 Link because they have been shown to be sensitive to noise originating from roads.

Results

Our results indicate the road effect zone of all options for the Hume Freeway F2 Link will fragment the grasslands of the Merri Creek Valley and reduce the quality of grassland habitat. Route Options 5, X, Y and Z are presented in Fig. 1. The impact of the road effect zones on the adjacent native grasslands is presented in Table 1. Upgrading the existing Hume Highway will have the least impact by placing the smallest amount of grassland in the road effect zone (151 ha) (Fig. 2) and potentially impacting only 13% of the existing grasslands. This option actually includes very little additional grassland in the road effect zone that is not already impacted by the existing Hume Highway road effect zone.

Option 5 potentially impacts 461 ha of native grassland, most of which is in the Craigieburn East Grassland which it bisects. Option X would have the greatest impact, placing 645 ha of grassland in the road effect zone (Fig. 3) and affecting 55% of the existing grasslands. It also crosses Merri Creek three times, significantly increasing the impact of the freeway because the road effect zone is wider at water crossings (Forman 1999). Option Y impacts 285 ha of grassland habitat and creates a barrier between the Craigieburn and Craigieburn East Grasslands while the road effect zone of Option Z is 427 ha. Option Z also crosses Merri Creek in three places. The road effect zone of Options X and Z encompass all of the Cooper Street and Galada Tamboore Grasslands. Option 5 and Option Y create road effect zones that completely engulf Galada Tamboore. These areas would effectively become unsuitable habitat for grassland birds. The area of grassland included in the road effect zone for each option is dependent on the width of the zone. Fig. 4 illustrates the area of native grassland remaining unaffected by road impacts with varying road effect zone width for each option.

Discussion

Many of the new and proposed freeways to the west and north of Melbourne traverse areas that contain remnant native grassland. Lowland temperate grasslands are among the most endangered ecosystems in Australia (Lunt 1994), and Western (Basalt) Plains Grassland which occurs in western and northern Melbourne is one of the most endangered vegetation communities in Victoria (Stuwe 1986; Frood and Calder 1987). It is listed as a threatened community on Schedule 2 of the *Flora and Fauna Guarantee Act 1988*, and is the subject of a Department of Natural Resources and Environment Action Statement (Muir 1994).

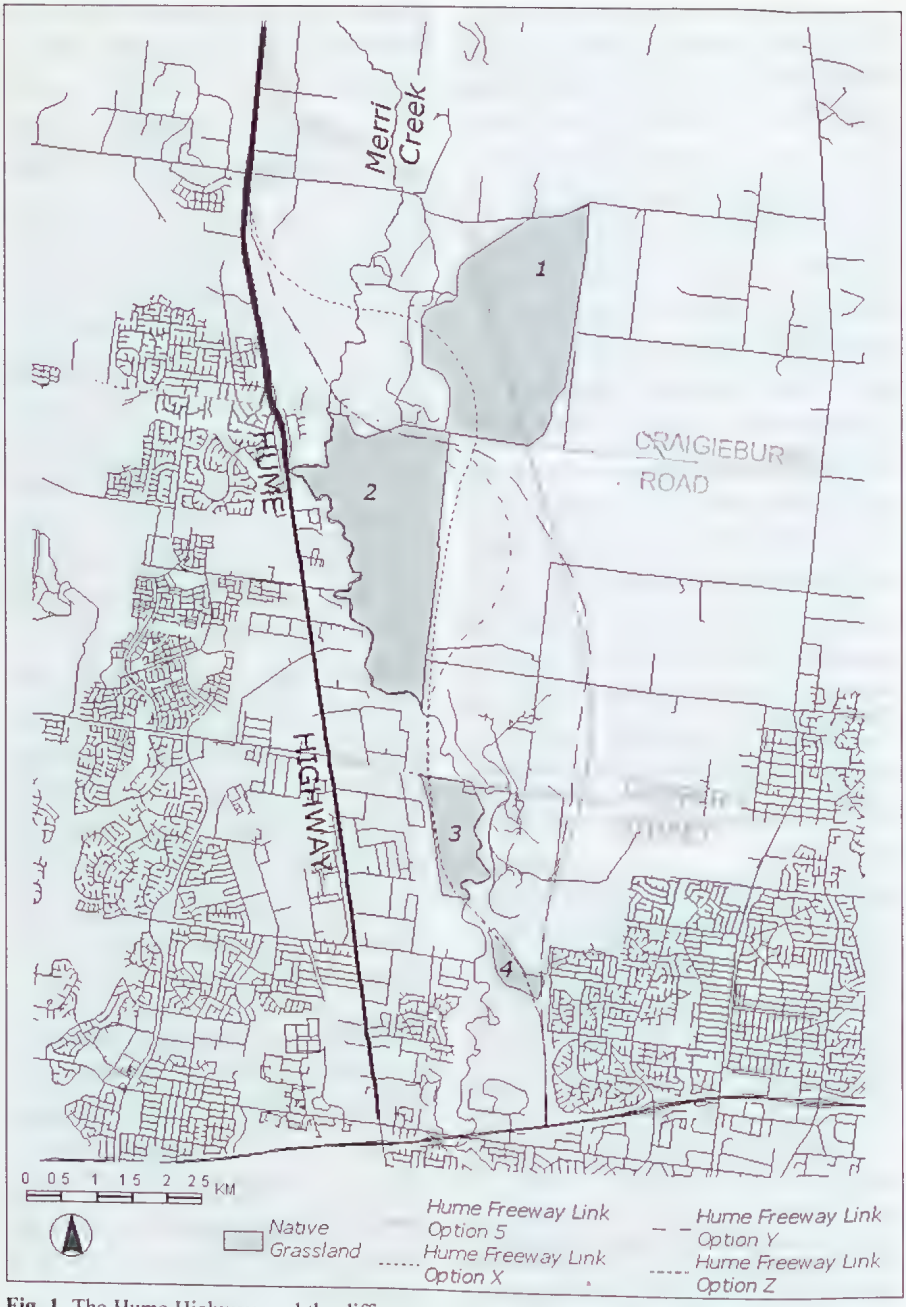

Fig. 1. The Hume Highway, and the different route options for the Hume Freeway F2 Link. Native grassland Reserves – 1. Craigieburn East, 2. Craigieburn, 3. Cooper Street and 4. Galada Tamboore.

Freeway construction has had significant, direct impacts on native grassland in the Melbourne region. The construction of the Western Ring Road destroyed many native grasslands. Substantial areas on the northern boundary of Derrimut Grassland Reserve and at the Sunshine Tip Grasslands that were of State significance

Table 1. The potential impact of the proposed Hume Freeway F2 Link on grasslands based on an estimated road effect zone of 750 m.

Route	Area of grassland in the 'road effect zone' (ha)	% of existing grassland habitat impacted by 'road effect zone'	Comments
Option 5	461	39	Craigieburn East Grassland split in half, Galada Tamboore lost
Option X	645	55	Largest area of grassland impacted by road effect zone
Option Y	285	24	Second smallest area of grassland impacted by road effect zone, Galada Tamboore totally included in road effect zone
Option Z	427	37	Two reserves totally included in 'road effect zone'
Upgrade of Existing Hume Highway	151	13	Only one reserve impacted by road effect zone, no grassland lost through road construction, no further fragmentation of grassland patches

were removed as were many smaller patches along the alignment (Meredith *et al.* 1989). Many of the route options for the proposed Hume Freeway F2 Link will cut through native grasslands of National and State significance to flora and fauna, including the Craigieburn and Cooper Street Grasslands that are listed on the register of the National Estate (Department of Infrastructure 2000; Muir *et al.* 1998; Muir *et al.* 2000).

Up to 52 ha of significant native grassland will be removed by the construction of the Hume Freeway F2 Link (Muir *et al.* 2000). Our analysis has indicated that many times this amount may potentially be influenced by the indirect impacts of the freeway. The area of native grassland within the road effect zone ranges from between 285 ha for Route Y to 645 ha for Route X. To date, little scientific research has been conducted on the indirect impact of roads on native grassland in Australia. Some studies have identified the expected effects of freeway projects on grasslands: permanent loss of remnant vegetation, permanent changes to the hydrological regime and increased potential for invasion by environmental weeds have been listed (Department of Infrastructure 2000; Meredith *et al.* 1989) but no one has sought to quantify them.

Morgan (1998) investigated the influence of a roadside edge as part of a larger study analysing weed invasion in an urban grassland at Evans Street, Sunbury. He found that vegetation located on the roadside edge of the remnant was significantly different floristically to vegetation in the centre of the reserve as well as the remnant edge bordering a railway line. Introduced plant species richness was significantly higher and richness and cover of native species was significantly lower at the remnant edge bordering the roadside than at all locations within the remnant. Soil nutrient analysis revealed that non-native species were favoured by higher concentrations of phosphorous and ammonium which were higher on the roadside edge of the remnant. Nitrate was also found to favour non-native species but was not found to be correlated with the roadside edge. Increased soil phosphorous and weed invasion did not extend beyond 10 m from the road edge into the grassland.

Higher nutrient concentrations and changes in plant species composition along the roadside edge at Evans Street Grassland cannot be solely attributed to the presence of a road as other influences such as nutrient input from dogs and occasional garden waste dumping may also be important (John Morgan *pers. comm.*). However, some contribution from traffic should be expected as vehicle emissions, such as carbon dioxide, sulphur dioxide and oxides of nitrogen, are known to act as fertilisers or affect plant growth (Angold 1997). Angold (1997) found that trends in the species

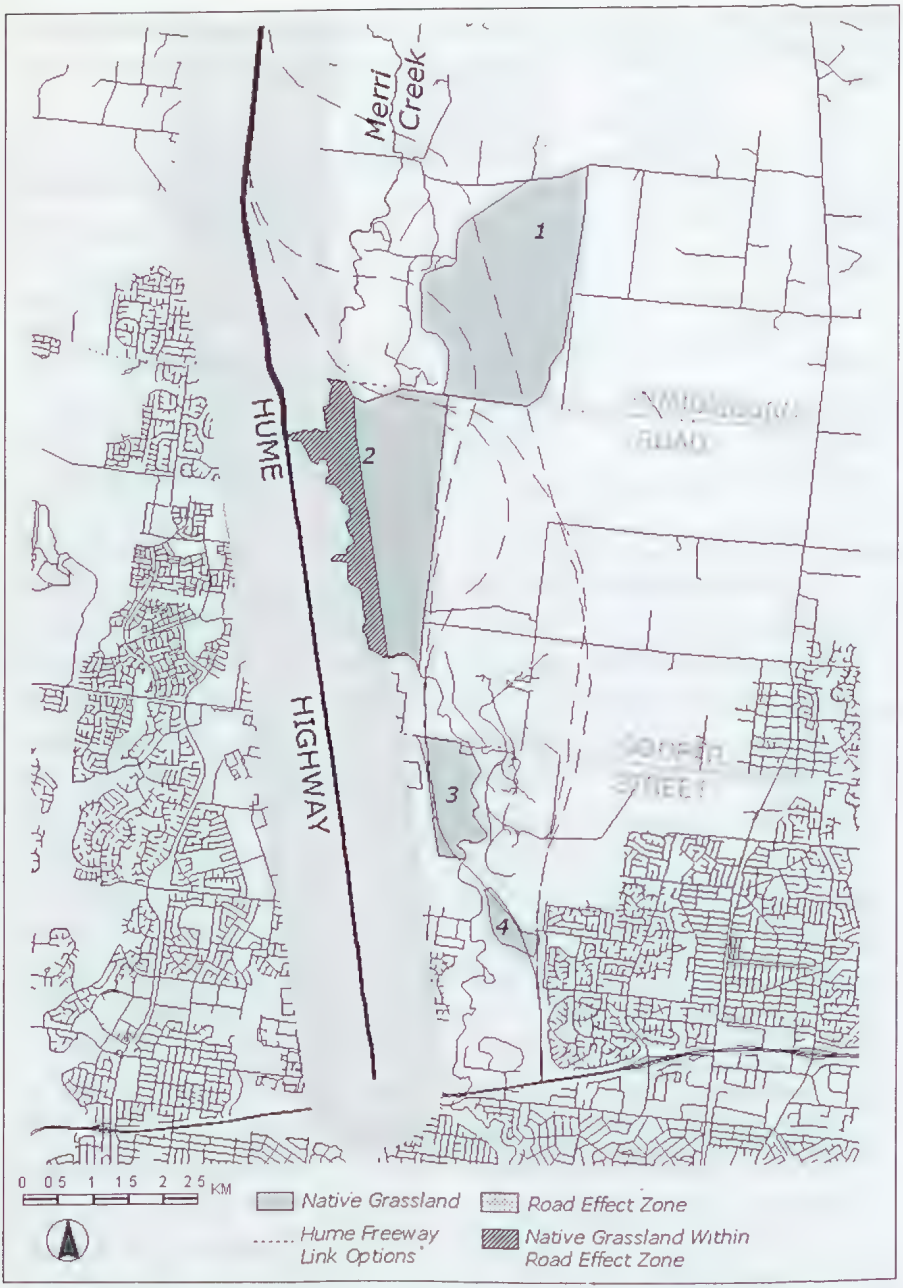

Fig. 2. Upgraded Hume Highway, with a 1 kilometre road effect zone. Affected areas of native grassland are shown with diagonal lines. Native grassland Reserves – 1. Craigieburn East, 2. Craigieburn, 3. Cooper Street and 4. Galada Tamboore.

composition and enhanced growth of heathland vegetation, adjacent to a four lane highway in Britain, were significantly correlated with distance from the road and that the effect extended up to 200 m each side of the highway. This was attributed to

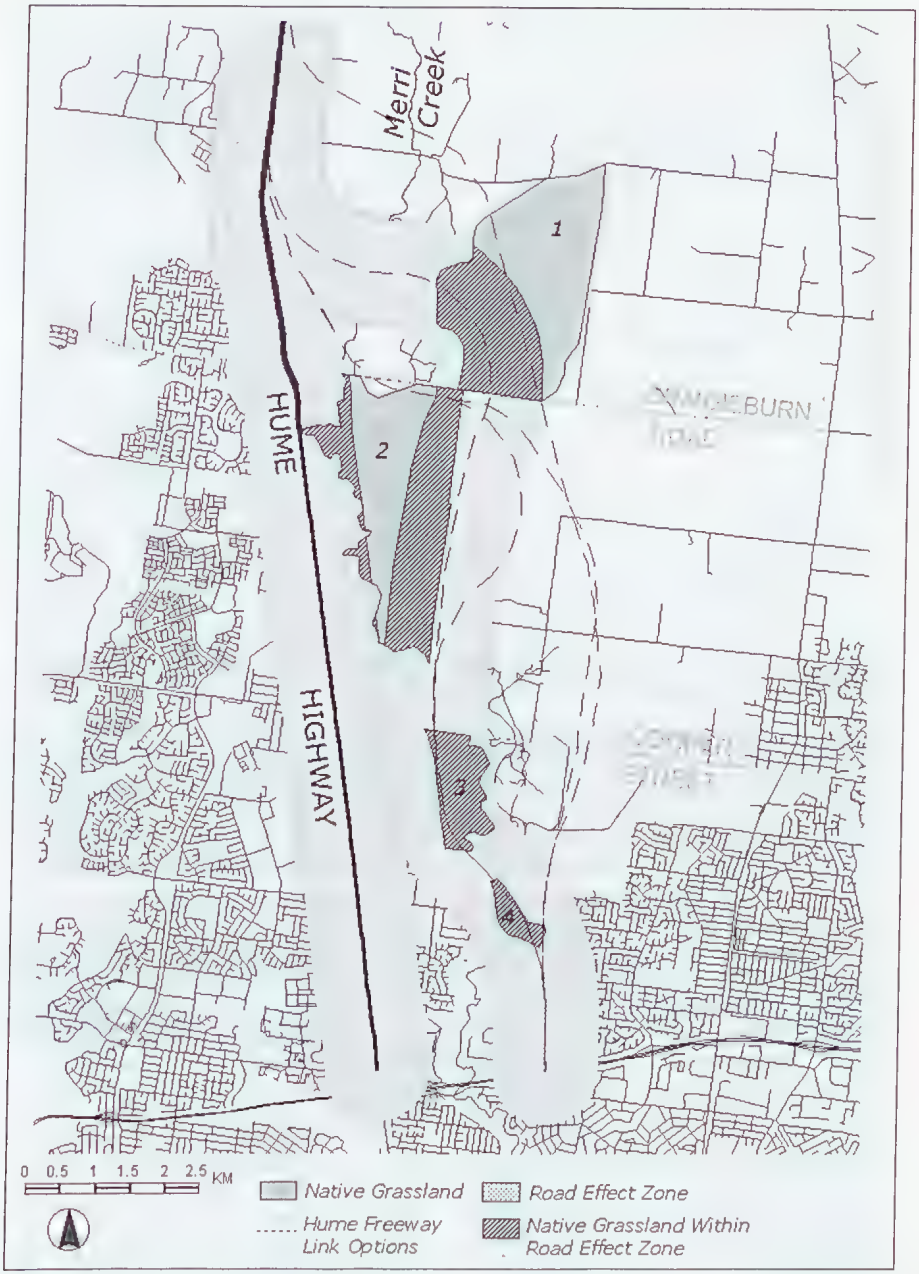

Fig. 3. Existing Hume Highway and Hume Freeway F2 Link Option X, with 750 metre road effect zone. Affected areas of native grassland are shown with diagonal lines. Native grassland Reserves – 1. Craigieburn East, 2. Craigieburn, 3. Cooper Street and 4. Galada Tamboore.

eutrophication from oxides of nitrogen emitted by vehicle exhausts. Similar effects and distances could be expected for grasslands bordering freeways in Australia.

Grasslands in the Melbourne region provide important habitat for populations of

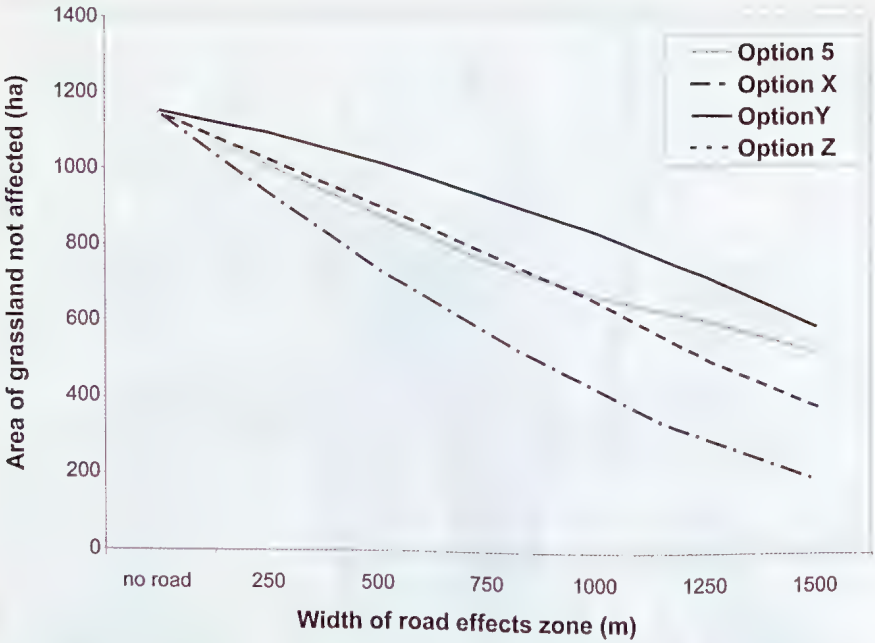

Fig. 4. The area of native grassland not impacted by the road effect zone with varying width of the road effect zone for each Hume Freeway F2 Link option.

many resident and migratory bird species. There are at least 20 grassland bird species recorded in the Melbourne area that are considered to be of conservation concern on either a regional, State or National level (Table 2) (Beardsell 1991; Beardsell 1997; Department of Natural Resources and Environment 2000). These include the nationally endangered Plains-wanderer *Pedionomus torquatus* and the Red-chested Button-quail *Turnix pyrrhothorax* which is listed as vulnerable in Victoria.

Table 2. Grassland bird species considered to be restricted (Res), rare (R), depleted (D), threatened (T), vulnerable (V) or endangered (E) for the Melbourne Region, Victoria and on a National level. Significance ratings have been obtained from Beardsell (1991; 1997) and Department of Natural Resources and Environment Victoria (2000).

Scientific Name	Common Name	Region	State	National
Accipiter cirrhocephalus	Collared Sparrowhawk	Res		
Calamanthus fuliginosus	Striated Fieldwren	D		
Cinclorhamphus mathewsi	Rufous Songlark	D		
Circus assimilis	Spotted Harrier	D		
Coturnix australia	Brown Quail	Res		
Falco peregrinus	Peregrine Falcon	Res		
Haliastur sphenurus	Whistling Kite	D		
Hieraaetus morphnoides	Little Eagle	Res		
Lathamus discolor	Swift Parrot	E	E	
Merops ornatus	Rainbow Bee-eater	D		
Milvus migrans	Black Kite	T		
Ocyphaps lophotes	Crested Pigeon	R		
Pedionomus torquatus	Plains-wanderer	E	E	D
Poephila guttata	Zebra Finch	D		
Stagonopleura guttta	Diamond Firetail	D		
Turnix pyrrhothorax	Red-chested Button-quail	E	D	
Turnix varia	Painted Button-quail	Res		
Turnix velox	Little Button-Quail	T		

A large body of Australian and international research has demonstrated that many birds that breed in grasslands require large habitat patches (Vickery *et al.* 1994; Herkert 1994; Baker-Gabb *et al.* 1990). Patches shaped to provide abundant interior areas, free from the impact of edges, have also been shown to maximise bird species richness. For example Red-chested Button-quail require patches of suitable habitat larger than 50 ha (Beardsell 1997), while areas favoured by the Plains-wanderer are approximately 200 ha (Baker-Gabb *et al.* 1990). Experts suggest that the conservation of the Plains-wanderer in north-east Melbourne will require the retention and management of the remaining patches of grassland. In addition, they recommend the linking of suitable native grassland habitat (Beardsell 1997). Given the ecological requirements of the species it is evident that a reserve supporting viable populations must be large (Beardsell 1997).

Freeways may also hinder or prevent the appropriate management of native grasslands. Western Basalt Plains Grassland requires burning at intervals not greater than 3 years to maintain native plant diversity and vigour (Lunt 1994; Morgan and Lunt 1999). However, it is difficult to achieve this aim for grasslands bordered by freeways as smoke may be a hazard to motorists. Bainbridge and Bush (2000) describe the complexity of conducting prescribed burns in urban areas while Lunt (1994) has identified the cultural, operational and financial difficulties of burning grasslands for conservation purposes. For Parks Victoria to burn the Laverton North Grassland Reserve wind must blow smoke away from a neighbouring petrochemical industrial plant and over the Princes Freeway. Consequently, burns must take place at night and require the employment of a traffic management group to close the freeway down to one lane that travels at 60 km/h. This dramatically limits the window of opportunity available to burn the reserve and as a result burns may be delayed until the following year (Fiona Smith, Parks Victoria Ranger in Charge, Melbourne Grasslands, *pers. comm.*).

Conclusion

Roads have both direct and indirect impacts on the environments they traverse. Apart from the direct removal of biota and the reduction and fragmentation of adjacent habitats, all roads contribute pollution, noise and exotic organisms to the surrounding ecosystem in a zone of variable width either side of the road. The existence of a road effect zone suggests that reserves may not fully protect the biological values of natural ecosystems if those reserves are in close proximity to freeways. This may be particularly true for native grasslands that require regular, active management and provide habitat for organisms susceptible to noise and other impacts of roads.

The two largest protected areas of native grassland in Melbourne, the Derrimut Grassland Reserve and the Laverton North Grassland Reserve, are both bordered by freeways. It is also proposed that the newly proclaimed Craigieburn Grasslands Flora and Fauna Reserve will be bordered by the Hume Freeway F2 Link to some degree. The road effect zone of the proposed route options for the Hume Freeway F2 Link would result in significant areas of the grasslands of the Merri Creek Valley being affected by noise, increased nutrients and other impacts of the freeway. This will further fragment the grasslands of the Merri Creek Valley and substantially reduce the area of suitable habitat available for grassland birds. In the past the indirect impacts of roads, highlighted by the road effect zone, have not been considered in the transportation planning process. Successful management and mitigation of all the environmental impacts of road projects dictates that the road effect zone should be considered. To facilitate this there is a need for research to quantify the nature and extent of the impacts of roads and freeways on Australian ecosystems.

Acknowledgements

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Editor's note: An interesting general article on the 'road effect zone' (REZ) appeared in *New Scientist*, 3 February 2001. Christie Aschwanden, in 'Tread Softly' on pp. 32-36, describes the theory of REZs and how disruption to the environment by road networks can be lessened.

One Hundred Years Ago

'A report of the dredging excursion on Saturday, 15th December, was read by the leader, Mr. J. Gabriel, who said that the Club was indebted to Mr. C.J. Cottell for the use of the yacht *Starlight* on the occasion. A start was made from the North Brighton pier at about 2.30 p.m., eleven members being present. The afternoon proved a very pleasant one, but, owing to the light wind, results were scarcely so good as had been expected, as time did not permit of the boat reaching the most favourable collecting grounds. Two dredges were employed, and a fair number of Mollusca, Crustaceans, and other forms of marine life were obtained. Amongst the shells found the most notable were *Meretria lamarcki* and *Cardita gunnii*, which were dredged, living, in fair quantities off Brighton Beach. Of the higher Crustaceans obtained *Ebalia (Phlyxia) intermedia*, Miers, and *Hymenosoma rostratum*, Haswell, are worthy of mention, as these forms are not included amongst our common littoral species.'

Excursion To Frankston

'Striking across the recreation ground towards Mt. Eliza the whole country was found to be a perfect flower garden, in which *Leptospermum scoparium* and *Ricinocarpus pinifolius* were conspicuous by their dazzling white flowers, while *Melaleuca squarrosa* scented the air with its rich honey-like perfume. A few insects of the commoner kinds were obtained by shaking. Crossing over some low-lying ground towards the cemetery the pretty *Utricularia dichotoma*, *Candollea calcaratum*, *Comesperma ericinum*, and other plants were seen at their best. Many years ago the beautiful pink orchid *Spiranthes australis* was to be found in this locality, but improvements have resulted in its disappearance. The singular plant *Drosera binata* grows here-abouts, along with that curious fern *Schizea fistulosa*. *Polypompholyx tenella*, *Sebaea albidiflora*, *Drosera pygmaea*, and *D. glanduligera* grew in abundance wherever there was permanent moisture. A few buprestid beetles, of which *Stigmodera maculata* and *S. xanthipilosa* were the most common, were taken, while some half-dead leaves of a eucalyptus, shaken into the umbrella, yielded several specimens of the pretty longicorn, *Ectosticta cleroides*. The little green beetle *Diphucephala rugosa* was very plentiful on the scrub. Very few orchids were seen, but the little plant *Comepserma calymega* reminded us that summer was rapidly approaching.'

From *The Victorian Naturalist* Vol. **XVII** - No. 10, February 7, 1901

Buxton Silver Gum Reserve: Using Geographic Information Systems to Investigate Historic Change in Site Integrity

Dianne Simmons[1], Robyn Adams[1] and Chris Lewis[1]

Abstract
Eucalyptus crenulata is a rare species known from only two populations. The Buxton Silver Gum Reserve was set aside in 1978 for the conservation of the species, but this objective may be compromised by changes in the integrity of the landscape immediately surrounding the Reserve. A time sequence of aerial photos and Geographic Information Systems technology has been used to identify patterns of landscape change, and aid in determining appropriate management strategies to minimize negative impacts caused by landscape fragmentation and habitat exposure. (*The Victorian Naturalist* **118** (1), 2001, 16-20.)

Introduction

Buxton Gum *Eucalyptus crenulata* Blakely & Beuz. is a rare and distinctive species with glaucous, crenulate heart-shaped leaves (see photo front cover). *Eucalyptus crenulata* is regarded as Vulnerable in Victoria (Gullan *et al.* 1990) and Vulnerable in Australia (Briggs and Leigh 1988). *Eucalyptus crenulata* is a relict species, having had a more extensive distribution in long-past wetter and colder periods. It is now found at only two sites in Victoria (Pryor 1981), and the suggestion that the species distribution has contracted in historic times due to European disturbance (Pryor 1981; Albrecht 1983; Jelinek 1991) is largely speculation. Due to the species' habitat specificity, it is more likely that at the time of European settlement, it existed as only two populations in two rare, isolated habitats embedded in a matrix of other native vegetation.

The species is confined to a specific and uncommon habitat (Pryor 1981; Prober and Austin 1990), and the habitat peculiarity of the two extant sites may be indicated by other rare species still found growing in association with *E. crenulata*. At the Yering site the rare *Pomaderris vacciniifolia* and *Pimelea pauciflora* are also present (McMahon *et al.* 1989), and there are a number of restricted species such as *Sphagnum cristata* and *Gymnoschoenus sphaerocephalus* at Buxton (Jelinek 1993). The site at Buxton may now represent a rare community rather than just a site with a single rare species.

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The Yering site (145° 21'E, 37° 41'S) adjacent to the Yarra River, has been cleared for well over a century and the hydrology has been extensively modified. Only a few trees of *E. crenulata* remain although there are a large number of hybrids (Simmons 1970; Jelinek 1991). Intensive management of this site is required if the natural population is to be restored and conserved. In contrast, the site at Buxton (145° 41'E, 37° 27'S), reserved in 1978 when the Buxton Silver Gum Reserve was established (Jelinek 1991), has a different landscape context, and potentially a very different management requirement. The site appears to be relatively intact, with few weeds, an uncommon combination of understorey species, and it contains a healthy *E. crenulata* population of approximately 600 adult trees (Adams and Simmons 2000).

Eucalyptus crenulata is easily propagated, and as a species it is not threatened with extinction. Past hybridization between *E. crenulata* and *E. ovata* at Yering has resulted in few trees which produce seedlings clearly assignable to *E. crenulata*, and which lack evidence of hybrization (Simmons 1970; Simmons and Parsons 1976; C. Fletcher 2000 *pers. comm.*). Conservation of the site at Buxton is particularly important as a seed source as the genetic resources of the species are still intact.

The Buxton population of *E. crenulata* is in an apparently secure Reserve. However, the viability of species and populations in reserves is affected by their landscape con-

The Victorian Naturalist

Index to

Volume 117, 2000

Compiled by K. N. Bell

Amphibians
Eastern Dwarf Treefrog, recent Victorian introduction?, 60
Giant Banjo Frog, in northern Victoria, 226
Limnodynastes interioris, in northern Victoria, 226
Litora fallax, recent Victorian introduction?, 60

Australian Natural History Medallion
Medallionist 2000, Malcolm Calder, 164
Trust Fund, 155

Authors
Adams, R., 36, 110
Adams, R.,Tunbridge, A. and Simmons, D., 44
Adams, R., Parker, D. and Lunt, I., 93
Akers, D. and Bender, R., 107
Appleby, M.L. and McDougall, K.L., 52
Bender, R. and Akers, D., 107
Bigger, S.W., Saville, T.A., Nugegoda, D. and Scarpaci, C., 4
Brewster, E., Thompson, B. and Lester, D., 157 (Tribute)
Calder, M., 194 (book review)
Cavanagh, T., 31, 114 (book review)
Christidis, L. and Norman, J.A., 219
Clarke, R., 118 (book review)
Clemann, N., 180
Clemann, N. and Gillespie, G.R., 60
Clemann, N. and Saddlier, S., 184
Cohn, H.M., 191 (book review)
Conole, L. and Mac Nally, R., 226
Coulson, G., Martin, A.A. and Martin, J.K., 140
Dean, J.C., 141
Diez, S., 38 (book review)
Doery, M.K., 77 (Tribute)
Eichler, J. 66
Endersby, I., 164
Faithfull, I., 68, 111
Ford, S. and Gibson, M., 172
Foster, E., 122 (book review)
Garth, K., 206, 227
Gibbens, J., 124
Gibson, M. and Ford, S., 172
Gibson, M. and Sinclair, B., 166
Gillbank. L., 112 (book review)
Gillespie, G.R. and Clemann, N., 60
Gilmore, D., 82 (book review)
Green, K., 214
Grey, M., 2, 116 (book reviews)
Homan, P., 75
Houghton, S., 130
Hubregtse, V., 156 (book review)
Lester, D., Thompson, B. and Brewster, E., 157 (Tribute)
Loos, T., 188
Lumsden, L., 117 (book review)
Lunt, I.D. and Parker, D., 207
Lunt, I., Parker, D. and Adams, R., 93
McNabb, E., Willig, R. and McNabb, J., 150
McNabb, J., McNabb, E. and Willig, R., 150
Mac Nally, R. and Conole, L., 226
McDougall, K.L. and Appleby, M.L., 52
McGee, T.K. and Miller, K.K., 200
Mahler, D. and Schleiger, N., 14
Maroske, S., 79 (book review)
Martin, A.A., Martin, J.K. and Coulson, G., 140
Martin, J.K., Coulson, G. and Martin, A.A., 140
Miller, K.K. and McGee, T.K., 200
Morgan, J.W., 50
Morton, A., 193 (book review)
Norman, J.A. and Christidis, L., 219
Nugegoda, D., Scarpaci, C., Bigger, S.W. and Saville, T., 4
O'Neill, P., 154 (book review)
Parker, D. and Lunt, I.D., 207
Parker, D., Adams, R. and Lunt, I., 93
Pearce, J., 84
Peter, J.M., 63
Romanowski, N., 162 (book review)
Saddlier, S. and Clemann, N., 184
Saville, T., Nugegoda, D., Scarpaci, C. and Bigger, S.W., 4
Scarpaci, C., Bigger, S.W., Saville, T. and Nugegoda, D., 4
Schleiger, N., 76, 190 (book review)
Schleiger, N. and Mahler, D., 14
Seebeck, J., 229
Simmons, D. Adams, R. and Tunbridge, A., 44
Sinclair, B. and Gibson, M., 166
Thies, A.W., 10
Thompson, B., Lester, D. and Brewster, E., 157 (Tribute)
Tunbridge, A., Simmons, D. and Adams, R., 44
Vafiadis, P., 228
Wainer, J.W. and Yen, A.L., 131
Wallis, R., 42 (Tribute)
Wark, M.C., 96
Weste, G., 187
Willig, R., McNabb, E. and McNabb, J., 150
Yen, A.L. and Wainer, J.W., 131

Birds

Acridotheres tristis, excluding from nest-boxes, 75
Acridotheres tristis, using letter boxes, 76
Birds and boxthorn, 63
Common Myna, excluding from nest boxes, 75
Common Myna, using letter boxes, 76
Helmeted Honeyeater, use of Mountain Swamp Gum, 84
Lichenostomus melanops cassidix, use of Mountain Swamp Gum, 84

Book Reviews

'Australian Rushes: Biology, Identification and Conservation of Restionaceae and allied families', Eds K.A. Meney and J.S. Pate. (N. Romanowski), 162
'Exploring Central Australia: Society, the Environment and the 1894 Horn Expedition', Eds S.R.Morton and D.J. Mulvaney. (H.M. Cohn), 191
'Feral Future', T. Low. (S. Maroske), 79
'Field Guide to the Birds of Australia', sixth edition, K. Simpson, N. Day and P. Trusler. (R. Clarke), 118
'Flora of Australia, vol. 1: Introduction', second edition. (L. Gillbank), 112
'Flora of Australia, vol. 17B, Proteaceae 3, *Hakea* to *Dryandra*'. (T. Cavanagh), 114
'Flora of the Nathalia District and Barmah Forest', The Nathalia Wildflower Group. (M. Grey), 116
'Grassland Flora: a Field Guide for the Southern Tablelands (NSW & ACT)', D. Eddy, D. Mallinson, R. Rehwinkel and S. Sharp. (S. Diez), 38
'Grassland Plants of South-eastern Australia', N. and J. Marriott. (S. Diez), 38
'Plains Wandering: Exploring the Grassy Plains of South-eastern Australia'. I. Lunt, T. Barlow and J. Ross. (S. Diez), 38
'Rock of Ages: Human Use and Natural History of Australian Granites', I. Bayly. (N. Schleiger), 190
'Sea Snakes: Australian Natural History Series', H. Heatwole. (P. O'Neill), 154
'Sherbrooke Forest: Its Flora and History', Friends of Sherbrooke Forest Inc. (A. Morton), 193
'The Bat: Wings in the Night Sky', M.B. Fenton. (L. Lumsden), 117
'The Koala: Natural History, Conservation and Management', R. Martin and K. Handasyde. (D. Gilmore), 82
'The Orchids of Tasmania', D. Jones, H. Wapstra, P. Tonelli and S. Harris. (E. Foster), 122
'WildGuide: Plants & Animals of the Australian Alps', B. Cameron-Smith. (V. Hubregtse), 156
'Wild Places of Greater Melbourne', R. Taylor. (M. Grey), 2
'William Dampier in New Holland – Australia's First Natural Historian', A.S. George. (M. Calder), 194

Botany

Anglesea vegetation regeneration project, 96
Banksia, recent literature, 31
Bladderwort, new Victorian record, 66
Boxthorn and birds, 63
Callitris glaucophylla, Jacksons Creek, 107, 110
Callitris glaucophylla, Maribyrnong, 36
Callitris spp, Terrick-Terrick National Park, 93, 207
Cypress Pines, Jacksons Creek, 107, 110
Cypress Pines, Maribyrnong, 36
Cypress Pines, Terrick-Terrick National Park, 93, 207
Dicksonia antarctica, lichens of, 172
Eucalyptus camphora, use as habitat by Helmeted Honeyeater, 84
Eucalytpus-Callitris woodlands, Terrick-Terrick National Park, 207
Hieracium auranticum, naturalized alpine species, 50
Ironbark forest, ant and termites in, 124
Lichens of Soft Treefern, 172
Lycium ferocissimum and birds, 63
Mosses in Melbourne Herbarium from Lord Howe Island, 10
Mountain Swamp Gum, use as habitat by Helmeted Honeyeater, 84
Native spp., germination effects of Sweet Pittosporum, 44
Orange Hawkweed, naturalized alpine species, 50
Pittosporum undulatum, allelopathic effects on native spp., 44
Plant invasions, North-east Victorian highlands, 52
Soft Treefern, lichens of, 172
Sweet Pittosporum, allelopathic effects on native spp., 44

Utricularia gibba, new Victorian record, 66
White Cypress Pine, Jackons Creek, 36, 107, 110
Wijkia extenuata, sexuality in wet Victorian forests, 166

Entomology
Ant and termite changes in Ironbark Forests, 124
Butterfly fauna, Paps Scenic Reserve, 131
Coleoptera addendum, Lake Mountain, 111
Termite and ant changes in Ironbark forest, 124

FNCV
Values and knowledge of members, 200

Honours
Ernest Perkins OAM, 67
Malcolm Calder, Australian Natural History Medallion, 164

Invertebrates
Macroinvertebrates, Yarra River, on erosional substrates, 141
Octopus kaurna, at San Remo, 228
Shell studies, Edwards Point, 14
Yarra River, macroinvertebrates, erosional substrates, 141

Localities
Anglesea, vegetation regeneration project, 96
Boronia, presence of Swamp Skink, 180
Edwards Point, shell studies, 14
Fitzroy Gardens, Water Rats in, 188, 206
Gunbower Island State Forest, Giant Banjo Frog, 226
Jacksons Creek, White Cypress Pines,107, 110
Lake Mountain, coleoptera addendum, 111
Lord Howe Island, moss collections in Melbourne Herbarium, 10
Mansfield, Paps Scenic Reserve, butterflies, 131
Maribyrnong, *Callitris glaucophylla*, 36
Mornington Peninsula, new Bladderwort locality, 66
Mullundung State Forest, Yellow-bellied Glider at, 150
Ovens flood plain, Giant Banjo Frog, 226
Paps Scenic Reserve, Mansfield, butterflies, 131
Port Phillip Bay, Bottlenosed Dolphin, 4
St. Leonards, shell studies, 14
San Remo, *Octopus kaurna*, 228
South Gippsland, Yellow-bellied glider, 150
Terrick-Terrick National Park, Cypress Pines, 93, 207
Yarra River, macroinvertebrates, 141
Yellingbo State Nature Reserve., habitat use of Mountain Swamp Gum, 84

Mammals
Bottlenosed Dolphin in Port Phillip Bay, 4
Hydromys chrysogaster in Fitzroy Gardens, 188, 206
Kangaroo death, 140
Nest hollows, sharing, 227
Petaurus australis in South Gippsland, 150
Platypus, paddle with, 187
Snow surface activity, small mammals, 214
Tursiops truncatus in Port Phillip Bay, 4
Water Rats in Fitzroy Gardens, 188, 206
Water Rats, general information on, 229
Yellow-bellied Glider in South Gippsland, 150

Miscellaneous
Anglesea, vegetation regeneration project, 96
Author guidelines, 234
DNA in Natural History studies, 219
Fifty years ago, 13
Flora and Fauna Guarantee Act, 95, 232
One Hundred years ago 106, 153, 183, 213
Origin of Easter Bilby *Macrotis lagotis*, 68
What are we eating?, 130

Reptiles
Austrelaps ramsayi, ritual combat, 184
Egernia coventryi, east of Melbourne, 180
Elliott traps, failure in skink survey, 180
Highland Copperhead, ritual combat, 184
Ritual combat in Highland Copperhead, 184
Swamp Skink, east of Melbourne, 180

Tributes
Ken Hamer (R. Wallis), 42
Ellen Lyndon OAM (E. Brewster, B. Thompson and D. Lester), 157
Elizabeth Kathleen Turner (M. Doery), 77

text, and by activities adjacent to the site. The isolation of fragments caused by land clearance often leads indirectly to habitat degradation due to the changed physical circumstances of the remnant (Saunders *et al.* 1991; McIntyre and Hobbs 1999). Thus reservation of significant habitat alone may not be sufficient to provide future protection for a species.

The interpretation of aerial photos can provide a history of landscape change (Hobbs *et al.* 1992), and mapping of landscape at different times can provide a good indication of landscape fragmentation and change (Worth 1996), and clarify fragmentation processes and their potential impacts on species conservation (Zheng *et al.* 1997). Geographic Information Systems (GIS) are a useful tool for monitoring changes identified in aerial photos, as they allow display at a range of scales, with the capacity to magnify areas of interest such as boundaries, and to readily calculate indices of landscape pattern and fragmentation (Simpson *et al.* 1994; Mast *et al.* 1997; Bruce *et al.* 1998) such as core areas or perimeter to area ratios.

Understanding the historic landscape context of a remnant, in this case the Buxton Silver Gum Reserve, can aid in determining the type of conservation management suitable for a particular remnant in a particular landscape context (McIntyre and Hobbs 1999). This study identified changes in land cover adjacent to the Buxton Silver Gum Reserve using historic aerial photos and Geographic Information Systems (GIS) technology, and used the pattern of landscape change detected to suggest appropriate management strategies.

Methods

Land cover mapping was carried out using unrectified black and white aerial photos. Sequential aerial photos were obtained for 1952, 1960, 1971 and 1987 (with nominal scales approximately 1:14,000). No more recent photographs of suitable scale are available. All photographs were digitized, georeferenced using GeoSmartimage® software, and then imported into ArcView 3.2® GIS software (ESRI 1996). Land cover classes were interpreted and digitized by a single operator for an area covering approximately 200 ha (one aerial photograph) immediately surrounding the Buxton Silver Gum Reserve. Vegetation was mapped as 'tree cover' versus 'no tree cover' as further distinctions between different vegetation types could not be reliably assessed (Mast *et al.* 1997). The present distribution of *E. crenulata* was also mapped from aerial photos and ground survey.

Results

Land cover maps showing the areas with tree cover/no tree cover and the present distribution of *E. crenulata* were produced (Fig. 1) and clearly indicate the loss of tree cover, and the increasing isolation of *E. crenulata* habitat over 35 years. In 1952 and 1960 tree cover was almost continuous, covering most (90%) of the study area, and surrounding most of the *E. crenulata* habitat. By 1987, less than half the study area had tree cover (45%) (Fig. 2a), and visual inspection of the area suggests that the land cover in 2000 is little altered from the 1987 situation.

The length of the perimeter bounding the *E. crenulata* site and the adjacent cleared areas also increased from only 150 m in 1952 to 575 m by 1987 (Fig. 2b).

Significant fragmentation of the treed area has occurred, increasing from one treed area (90%) and one cleared area (10%) in 1952 to seven fragments by 1987 (Fig. 1). Five of these fragments are less than 1 ha in area. The remaining two 'fragments' are actually part of larger areas of forest which continue beyond the arbitrary boundary of the study area; the larger of these surrounds the site on the northern and western perimeter, and the other is approximately 800 m to the east. Nine trees have been isolated in a small fragment on private land on the northern edge of the Reserve, but no reduction in area or decrease in tree cover of the actual *E. crenulata* population within the Reserve was detected.

Discussion

Habitat destruction is the loss of structural and floristic features of the original vegetation (McIntyre and Hobbs 1999), and can be expressed simply by differentiating between those areas with tree cover and those areas with no tree cover. The historic

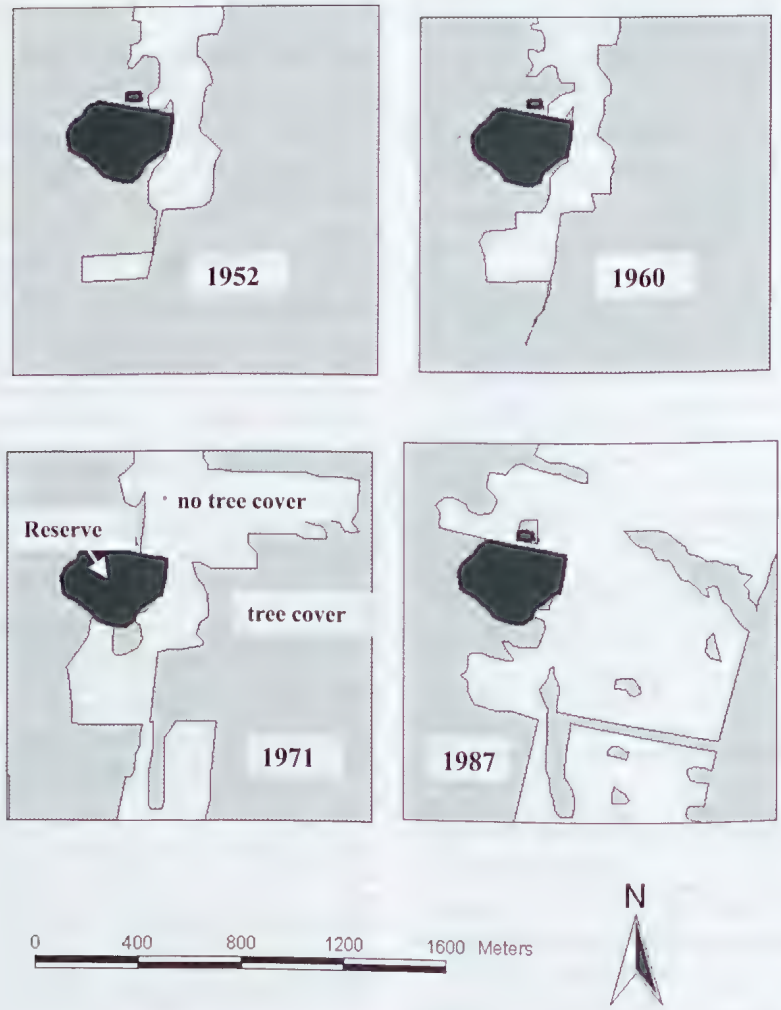

Fig. 1. Changes in land cover category from tree cover to no tree cover for the area surrounding the Buxton Silver Gum Reserve, between 1952 and 1987.

sequence of land cover maps showed no detectable reduction in the area occupied by *E. crenulata.*

However, for the area surrounding the Buxton Silver Gum Reserve they clearly indicate loss of tree cover, significant fragmentation of the original treed area, and increasing isolation of *E. crenulata* habitat. McIntyre and Hobbs (1999) suggest that the threshold for a shift to a 'fragmented' landscape occurs when habitat retention (tree cover) is less than 60%. In the area immediately surrounding *E. crenulata*, retention of tree cover is now much less (45%) than this threshold. Many ecosystem processes can be disrupted when habitat becomes isolated and the remaining fragments are embedded in a matrix of cleared land (Saunders *et al.* 1991). Among the potential threats to the internal integrity of *E. crenulata* habitat, are fungal attack (*Phythophthora cinnamomi* has been detected in soil in the Reserve), Coarse Dodder-laurel *Cassytha melantha* infestation (41% of trees are infested), weed invasion, and lack of recruitment.

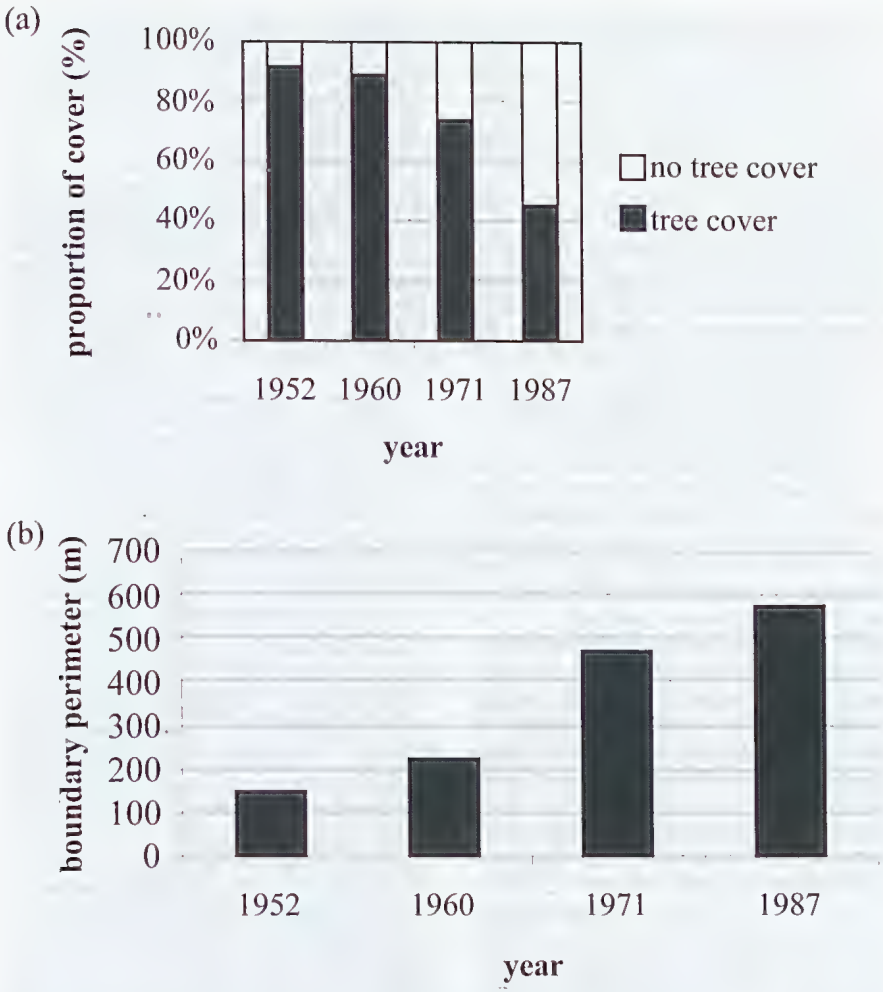

Fig. 2. Changes in (a) the proportion of the study area covered by trees (% of 200 ha) and (b) boundary perimeter (m) exposed to adjacent cleared areas, between 1952 and 1987.

There are about 600 adult trees at the site, but few seedlings of *E. crenulata* are present and the population is skewed to smaller size classes with few large trees (Adams and Simmons 2000).

Although there has been a large increase in the length of perimeter of the *E. crenulata* habitat exposed to cleared areas, about 60% of the site perimeter is still adjacent to treed areas. However, the simple binary division between tree cover and no tree cover may underestimate the disturbances impacting on the Reserve (McIntyre and Hobbs 1999). Adjacent areas of habitat mapped as tree cover may have been significantly modified. Some of the adjacent large areas of forest have been logged, and the Buxton Silver Gum Reserve now forms part of a variegated landscape (McIntyre and Hobbs 1999) comprising treed areas with various degrees of modification through to completely cleared areas. The degree of exposure of the Buxton Silver Gum Reserve may greatly increase the likelihood of negative impacts on the ecological functioning of the *E. crenulata* population.

From a management perspective, using aerial photos and GIS capabilities to

examine the landscape changes in the area surrounding the Buxton Silver Gum Reserve, has allowed the identification of a trend towards increasing isolation and exposure of the site to the physical changes, such as wind and light regimes, associated with fragmentation (Saunders *et al.* 1991). While investigation of the ecology of *E. crenulata* continues (Adams and Simmons 2000), one immediate and potentially highly effective management action is to decrease the exposure of the site by restoring a vegetated buffer to reduce the abrupt boundary interface between the *E. crenulata* population and the cleared areas. However, most clearing has occurred on private land and the opportunities to reduce isolation of the Buxton Silver Gum Reserve are limited without participation and involvement of adjacent landholders.

Like *E. crenulata*, a number of other *Eucalyptus* species are known to be restricted to unique habitats (Prober and Austin 1990). However, reservation of the habitat alone may not be sufficient to provide protection for a rare community or a rare species because of potential climatic changes (Prober and Austin 1990) or changes to the landscape context and land-use adjacent to the habitat (Saunders *et al.* 1991; McIntyre and Hobbs 1999). Rare habitat may need to be surrounded by a matrix of other vegetation in order to be buffered from the altered physical processes which accompany fragmentation (Saunders *et al.* 1991). Even common species can become threatened by the accumulation over time of small, individual changes to landscape integrity (Worth 1996). *Eucalyptus crenulata* at the Buxton Silver Gum Reserve provides an example of the how the use of aerial photography and GIS technology can be combined to identify fragmentation processes and their potential impacts, and aid in suggesting appropriate management strategies for the conservation of other restricted species.

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Yarrow *Achillea millefolium* L.: a Weed Threat to the Flora of the Australian Alps

Frances Johnston[1] and Catherine M. Pickering[1]

Abstract
Yarrow (Milfoil) *Achillea millefolium* L. is a potential threat to the native subalpine and alpine plant communities of the Australian Alps. Although Yarrow has been found in Kosciuszko National Park for the last 50 years, it has extensively colonised subalpine disturbed habitats, including roadways, during the last decade. Currently, isolated plants can be found in adjacent native vegetation, and a few plants have been found and removed from areas as high as 2000 m along the summit of the main range. Research is currently being conducted on the biology and control of this 'most hardy weed … well named for the invulnerable Achilles' (Georgia 1942). (*The Victorian Naturalist* **118** (1), 2001, 21-24.)

Yarrow *Achillea millefolium* L. (Asteraceae), is a drought tolerant perennial herb with rhizomatous vegetative growth (Fig. 1). It is native to Europe and Western Asia (Zhang *et al.* 1996). Aromatic pinnately dissected leaves are produced in a basal rosette and along the flowering stem. Both stems and leaves are covered with short, white, silky hairs. The flower heads are arranged in a corymbiform inflorescence, each head consisting of around 5 ray flowers (usually white, pink or magenta) and 20-25 disk flowers. Flowers are self-incompatible with an extended flowering period from spring to autumn. Achenes, produced in large numbers, are oblong, 1.5-2.0 mm long, and grey-white in colour (Rydberg 1916; Chandler *et al.* 1982; Warwick and Black 1982).

Yarrow grows throughout south-eastern Australia where it is often cultivated as a popular garden plant and lawn substitute (Thorton-Wood 1999). Although often sold in nurseries, it is regarded as an environmental weed in the Australian Capital Territory, New South Wales and Victoria (Anon 1998; Sainty *et al.* 1998; McDougall and Appleby 2000).

Throughout the Australian Alps, Yarrow grows along roadsides and around buildings (Costin 1954; McDougall 1982; Mallen-Cooper 1990; Sanecki 1999, Figs 2 and 3). Although recorded as early as 1949 in grasslands in the subalpine zone of Kosciuszko National Park (NSW Soil Conservation Herbarium database), populations of Yarrow appear to have increased rapidly in Kosciuszko National Park during the 1990s (R. Knutson, NSW National Parks and Wildlife Service, *pers. comm.*; Sanecki 1999). The increase in Yarrow is possibly associated with the use of gravel from weed-contaminated dumps in the construction of roads and other infrastructure (R. Knutson, NSW National Parks and Wildlife Service, *pers. comm.*). Recent surveys found Yarrow in all four zones (alpine, subalpine, montane and tableland) of Kosciuszko National Park, predominantly in highly disturbed sites. Potentially of most concern are isolated Yarrow plants that have recently (since 1998) been found in the alpine area along the old Summit Road and the Main Range walking track, as well as around Seamans Hut in the true alpine zone.

Where populations of Yarrow occur on road embankments, roadside drains and other disturbed sites (Fig. 4), our surveys indicate that isolated plants are often found in the adjacent native vegetation (Table 1). This indicates that Yarrow has the potential to spread from disturbed areas into native vegetation.

Achillea millefolium is potentially a serious threat to the vegetation communities of the high altitude areas of the Australian Alps. It has broad environmental tolerance, including a capacity to thrive on a range of soil types, and in a range of climates (from arid to alpine; Clausen *et al.* 1958; Bourdot 1984). It is a common weed in many temperate countries including most of North America, Canada, Russia, temperate Europe, New Zealand and Australia (Clausen *et al.* 1958; Bourdot 1984). When

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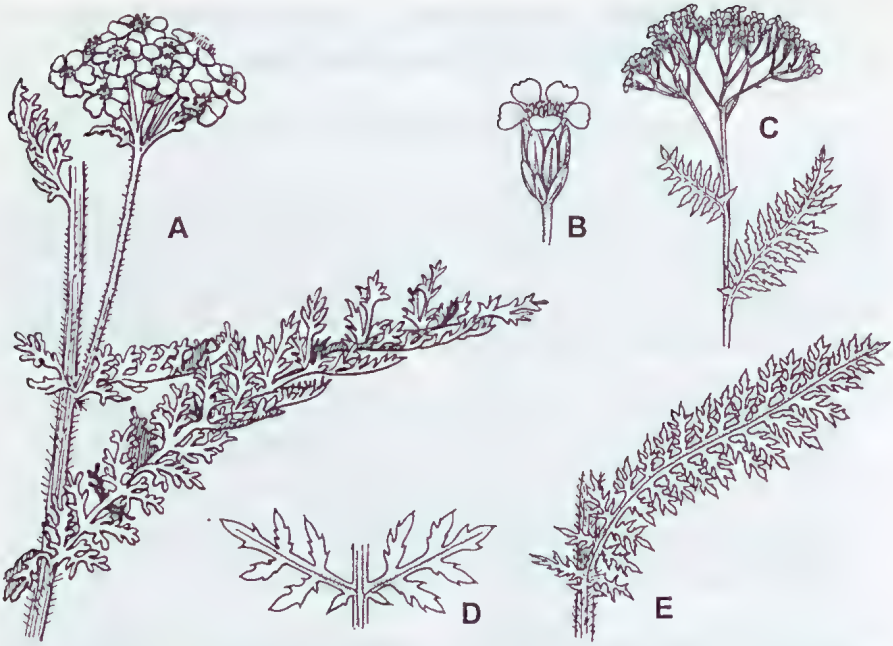

Fig. 1. Inflorescence and leaves of Yarrow *Achillea millefolium*. A. Lateral corymbiform inflorescence and cauline leaves. B. Individual head. C. Terminal branched corymbs. D. Leaflet. E. Cauline leaf. Modified from Stanley and Ross (1983, A), and Hardin (1992, B-E).

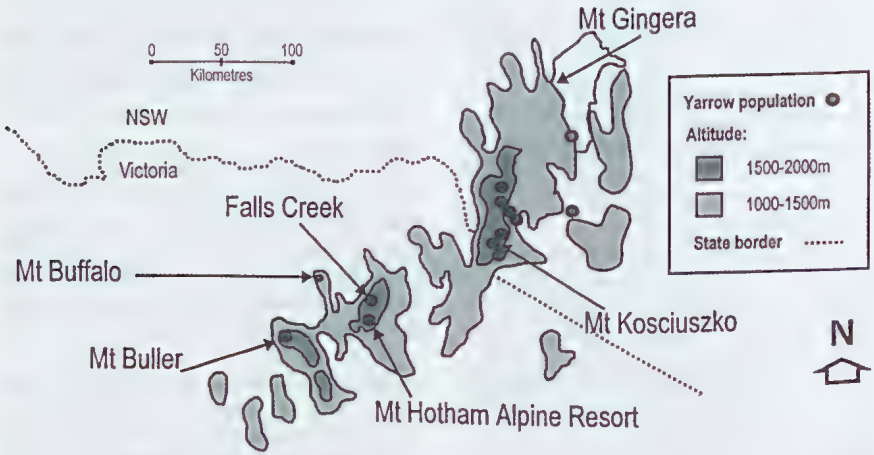

Fig. 2. Populations of Yarrow in the Australian Alps. Areas above 1000 m, 1500 m marked. Locations from Mallen-Cooper (1990), Sanecki (1999), McDougall and Appleby (2000) and present study. Map modified from Green (1994).

allowed to spread unchecked in the forests of Siberia, it forms an understorey monoculture (Banks, Australian National University, Canberra, *pers. comm.* 1999).

A series of attributes, including high seed production, rapid seedling growth, long-term seed dormancy, rhizomatous growth and strong competitive ability, contribute to Yarrow's invasive potential in high altitude areas (Henkens *et al.* 1992). Yarrow

Table 1. Recorded occurrences of Yarrow plants in native vegetation near populations growing along roadsides in Kosciuszko National Park.

Location	Latitude, Longitude	Altitude (m)	Distance to road (m)	Vegetation type
Geehi River Bridge	36°17', 148°18'	1400	5	Subalpine grassland
Dicky Cooper Creek	36°15', 148°21'	1860	6-15	Tall alpine herbfield
Orange Hut	36°16', 148°23'	1700	1	Subalpine grassland
Valentines Hut	36°16', 148°23'	1700	3	Subalpine open woodland
Shlinks Pass	36°15', 148°25'	1800	3	Subalpine heath
Guthega Power Station Gate	36°20', 148°25'	1600	3	Subalpine open woodland
Perisher Pass	36°24', 148°25'	1700	3, 8, 22, 28, 39	Subalpine grassland
Smiggins Hole Sewage Ponds	36°23', 148°26'	1700	40	Subalpine grassland
Seamans Hut	36°28', 148°16'	2000		Tall alpine herbfield
Twynam Ridge	36°35', 148°20'	2000		Tall alpine herbfield
Daners Gap	36°22', 148°28'	1700	30-40	Subalpine grassland

shows limited wind dispersal with most seed found within a few metres of the plant (Bourdot *et al.* 1979). However, contamination of gravel and mulch appear to have assisted its dispersal in Australia and overseas (Bourdot and Field 1988; R. Knutson NSW National Parks and Wildlife Service *pers. comm.*). Yarrow also has many of the characteristics of other rhizomatous weeds including bud dormancy, strong apical dominance broken by disturbance, and rapid vegetative propagule formation on fragmentation (Bourdot 1984); characteristics that facilitate the growth and spread of the plants in new habitats.

Studies in New Zealand on methods to control Yarrow indicate that both different herbicides (bromacil, terbacil, clopyralid, chlorsulfuron, phenoxy, triazine, urea, dinitroaniline, benazolin, bentazone and oxyfluorfen) and other control measures have limited success (Bourdot *et al.* 1982; Bourdot and Butler 1985; Field and Jayaweera 1985; Bourdot and Field 1988). Preliminary results from chemical trials on Brush-off (7 g/100 L), Banvel/Amicide (500 ml/100 L), Glyphosphate (1000 mL/100 L and Grazon (500 mL/100 L) conducted in subalpine areas of Kosciuszko National Park support these

Fig. 3. Frances Johnston assessing cover of Yarrow *Achillea millefolium* growing on roadside in the subalpine zone of Kosciuszko National Park. Photograph by C. Pickering.

Fig. 4. Dr Alec Costin, Dr Pickering, and NPWS Soil Conservation Officer Stuart Johnston examining Yarrow growing on Mt Twynam. Photograph by C. Kelly.

results. They show that the recommended chemical control for Yarrow in the Australian Alps is having little effect on containing the vegetative spread of the weed (Sanecki 1999).

To better quantify the threat of Yarrow in Kosciuszko National Park a four-year study into the population dynamics and invasive biology of the species is being conducted. In addition, the New South Wales National Parks and Wildlife Service is conducting chemical efficacy trials. Preliminary findings of both projects indicate that the emphasis for control of Yarrow must be placed on long-term management that involves the prevention of rhizome growth, suppression of seedlings, and seed and rhizome eradication. In rehabilitation work like this, alternative measures such as biological control and the use of competitive native species need to be investigated in addition to the selective use of herbicides (Crawley 1997). Effective management during the construction of infrastructure is also vital. This includes reducing site disturbance and using uncontaminated earth-construction materials. The trick is to find Yarrow's Achilles heel.

Acknowledgements
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Celebrating Our Parks – Proceedings of the First Australian Symposium on Parks History

(Mount Buffalo, 16-19 April 1998)

Elery Hamilton-Smith (ed.)

Available from: *Rethink Consulting, P.O. Box 36, Carlton South, Victoria 3053. ISBN 0 646 36675 0*
$35.00 (plus $8.50 handling and postage)

The history of conservation and the national park concept are under-researched fields in Australia, even though we have a long and deeply felt tradition about these matters, and plenty of reason to be interested in them for practical reasons. This seems surprising, as parks are generally a positive and enjoyable aspect of things environmental and it would seem more likely, therefore, that people would be keen to study them and in so doing, to celebrate them. Given the depressing nature of a good deal of news and ideas about 'the environment', the stories of substantial vision, achievement and continuing community commitment to our Parks system could do with more attention than they get.

The Symposium 'Celebrating Our Parks' and its Proceedings which are the subject of this review, was a successful and noteworthy attempt to address this deficiency. The Symposium was one of the events which celebrated the centenary of National Parks in Victoria, and Mount Buffalo National Park in particular. Elery Hamilton-Smith not only organised the Symposium, but also edited and published its Proceedings. The papers included in the Proceedings cover a good representation of the history makers of recent generations. These are from the former Premier, Sir Rupert (Dick) Hamer, and two former Directors of National Parks in Victoria (Don Saunders and John Brookes). Other well known figures in policy and recording of policy in recent times are also included, such as National Parks Advisory Council members Geoff Durham and Rachel Faggetter, and the first Parks Planner (and cultural historian) Jane Lennon. There are also contributions by rangers, historians, current administrators, and community members. In addition, papers are presented from a strong contingent of overseas and interstate speakers, including Susan Markham from Acadia University, Nova Scotia. Her papers, and those from New Zealand, Queensland, Tasmania and New South Wales, bring out many of the parallels between Park systems in Canada and Victoria and the other States. Therefore this collection of papers on park history offers a varied, broad, personal and authoritative overview of a huge range of ideas, issues and experiences.

The papers are fairly loosely organised under the headings: Building the Victorian National Park System, Parks in a Cultural Context, Victoria's Alpine Parks, A Diversity of Parks, Wider Perspectives on Parks, and People and National Parks. Across these broad groupings, several themes emerge repeatedly.

Some of these are:

- The significant role played by many individual citizens. At first this role was in contesting the general exploitation of public land, as well as in establishing, defining and maintaining a statewide system of reserved land. Then later, it was in pioneering the parks system. These citizens include scientists, public servants and community activists such as von Mueller, Stirling, Baldwin Spencer, George Perrin, Crosbie Morrison and Ros Garnet, who not only had the vision and took the lead but also inspired countless other Victorians to support them and to love and serve their parks.
- The range of bodies associated with parks and park management. These

include those who fought for them, the Field Naturalists Club of Victoria, the Town and Country Planning Association and the VNPA. There are those that determined their existence - the visionary Bill Borthwick and the LCC; those that managed or administered them - Committees of Management which ran many parks up until 1975; and various versions of a National Park Service with its many committed public servants. There are those who developed them - the Victorian Railways and the RACV. And of course those that opposed them – the Forest Commission, many Shire Councils, resource user groups.

- The way in which the same battles between the same kinds of protagonists are fought time after time. This is 'the tug-of-war between those who would exploit public land in all its forms and those who would preserve it' as described by Dick Hamer. This struggle continues in each generation. The outer appearance of the argument fluctuates, taking on the form of the current buzz idea to validate economic exploitation, but the inner values remain the same, as do the ingredients that lead to successful defence of the Parks system.
- The significance of, and interest in, the cultural heritage of our parks. This quality is not well recognised in their management, nor is the fact that it enriches rather than diminishes the value of the parks for most visitors. Despite our admiration for qualities such as 'pristine' and 'wild', it is the 'people places' and the 'people experiences' that draw us and intrigue us on most visits, or the recorded stories, rather than the remote and unpeopled landscapes. Yet even today, cultural heritage does not attract its share of attention as an important aspect of our Parks, compared with the dominance of ecological ideas such as protection of significant vegetation species or communities.

This Proceedings contains many stories and points of view that are not easily available elsewhere, as they are 'from the horse's mouth' - current and personal, offered by people who were doing important tasks for the first time. I have used several of them in teaching Parks and Wildlife Management to undergraduates, especially Hamilton-Smith's 'Changing assumptions underlying national park systems' and Don Saunders' 'Towards a representative system of conservation reserves for Victoria'. I would therefore recommend the Proceedings strongly for teachers of natural resource management and libraries where these matters are taught.

Despite the length of history in our parks system, so much that needs to be recorded, shared and reflected upon is very recent and still resides mainly in people's heads and filing cabinets. And our Parks are under constant pressure, both positive and negative, to take on new directions and purposes, before we have adequately recorded or reflected on the old ones. The value of this Proceedings lies in the wealth of personal knowledge and philosophy it contains, and in the sense of pride it communicates in the achievements so far. This Proceedings is an invaluable aid to the important task not only of recording history as a basis for establishing traditions, but also for interpreting or critiquing them.

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Kosciuszko Alpine Flora
Second Edition

by A.B. Costin, M. Gray, C.J. Totterdell and D.J. Wimbush

Publisher: *CSIRO Publishing, 2000. Hardback, 404 pp., colour illustrations, maps, photographs. ISBN O643065229. RRP $59.95*

The first edition of this work, published in 1979, received national and international acclaim, and this second edition will no doubt be similarly well received. Although the title emphasises the contents related to the flora of the area, the book is far more comprehensive. Human association, from annual Aboriginal excursions, to early exploration by Strzelecki and others, the beginning of the pastoral runs, the work of Mueller, the development of tourism, and the impact of the Snowy Mountains Hydro-electric Scheme, is briefly but comprehensively covered in the second chapter. The first chapter clearly defines, by word and illustration, the terms of reference concerning the alpine and sub-alpine environments.

In the third chapter there is an extensive treatment of geological evolution of the Kosciuszko Alpine Area which is essential to a proper understanding of the distribution of the various plant communities. Our Gondwanan connections are analysed and the sculpting of the present landscape is dealt with in some detail. For the geologically challenged, this is clearly explained with the assistance of an excellent glossary, line drawings and a series of colour photographs delineating the diversified landscapes. In these years of concern with global warming and its possible effects on climate, there is some timely data about the extensive modifications that can occur with a variation in temperature of as little as 3°C.

Having mastered the basic geology, it will become clear in the fourth chapter why the various plant communities occur where they do. The authors define eight distinct communities, give several examples of the characteristic species to be found in each and where such communities are likely to be found. Once again, the detail is assisted by clear definitions, more than two dozen colour photographs, clear diagrams and a colour coded map in the form of an endpaper. A similar map was given in the first edition, in two sections, as part of the text. It must be said that the endpaper in this edition is easier to understand than the maps in the former, but that it lacks any reference to the contour intervals or altitude of reference points.

This chapter is essential in understanding why species occur where they do. It also helps the understanding of why there are apparent disjoint distributions, why habitats may contain variations in the general scheme, and the manner in which the vegetation of a given area can alter even without the interference of the human element.

These essential introductory chapters occupy less than one fifth of the book, and the next seven pages comprise a list, in taxonomic order, of the 212 native species, subspecies and varieties occurring in the Kosciuszko Alpine Area. In addition, a key is added referring the habitats to the eight plant communities defined previously. The 21 endemic species are clearly indicated. Over 260 colour plates follow. Some of these plates contain separate images salient to the identification of the plant, and all have captions referring to distinguishing features and size. The photographs are not to any particular scale, and some have been magnified as an aid to identification, as they would be with a hand lens. Reference to the notes on identification and description will clarify any problems with size.

A twelve page bibliography, referable back to the text, will allow the keen student to follow up on any or all of the aspects covered in the book. The following

142 pages of taxonomic information brings this edition up to date with current knowledge published in the Floras of Victoria and New South Wales, as well as in the volumes of the *Flora of Australia* published so far. No apologies are offered for the reasonably technical nature of this section, the use of which is enhanced by a twelve page glossary of botanical terms. Throughout the descriptions there are cross references to the relevant illustrations. Finally there is a very full index, each species named having a reference to the pages on which the description occurs, its appearance in the general text and the relevant colour plate.

In addition to this hardback volume, there is a paperback **Kosciuszko Alpine Flora Field Edition** of 245 pages by the same publisher and authors. This contains the same material as the hardback with the exception of the taxonomic identification and description. This shorter edition is priced at $29.95.

This beautifully produced book is now available, and as the reviewer said of the first edition, 'see it and you'll want to possess it'!

R.J. Fletcher
28 Marjorie Avenue,
Belmont, Victoria 3216.

We regret to announce the death of Dr George Thomas. George, an Honorary Member, had a long association with the club, and had been a member since 1942. An obituary will appear in a later issue.

We were also saddened to hear of the death of Stefanie Rennick on 3 January, 2001. Stefanie was tireless in her commitment to conservation of the flora of the Mornington Peninsula. A tribute to Stefanie will appear at a later date.

A Second Assistant Editor

We are pleased to welcome Anne Morton as Assistant Editor for *The Victorian Naturalist*. Anne has worked as a desktop publisher on the journal since 1997. We are looking forward to working with Anne on your journal, where her expertise in administration, proof-reading and desktop publishing will be welcome.

Anne is a biologist and her field of interest is the ecology of foxes in an urban environment.

Merilyn Grey and Alistair Evans

John Paul Stewart

2 February 1934 – 21 December 2000

John Paul Stewart was born in Footscray on 2 February 1934. John was a good child and his father once said he could not recall having smacked him, nor was there any need for serious remonstration. John attended St. John's School in West Footscray. He then won a scholarship to attend St. Joseph's Technical College in South Melbourne. He became dux in his last year there.

During his late teens, John took an interest in photography. He enjoyed taking photographs of friends' weddings and babies and he developed the pictures himself. In later years John spent more time and film photographing grass seeds, flowers and unusual fungi found in the western suburbs.

John started work as an apprentice plumber at Maize Products, Footscray. He did his stint of National Service training in the 50s. He said he finished his training the fittest he had ever been in his life. John loved ballroom dancing and went to such events at every opportunity. He also enjoyed underwater fishing, but it lost its appeal the day he almost drowned.

John worked at the Fawkner Crematorium and Memorial Park from 1968 until his retirement in February 1999. In the last 30 years he had many interests. Time was spent with his children driving them to calisthenics, tennis, cricket, school functions, speech and drama classes. He said it never failed to be a miserable night, weatherwise, for parent-teacher interviews. When the local scout group needed a leader at different times, John took on the role over a period of 15 years and as a result attended scout jamborees all over Australia.

He had many interests – weaving, gemstones, Adult Education Association Geology and finally as a field naturalist. I first got to know John through AEA Geology. It was the practice after taking an Adult Education Geology course to join the AEA Geology Group and continue one's interest with lectures and excursions in the Association. At the time John was President of that group and he convinced me to lead excursions to central Victorian geology sites.

When John was involved with AEA Geology and the Melbourne University Geology Department, he went on field trips all over outback Australia as their cook. (He had never peeled a vegetable at home!) He kept journals of his many trips and in later life used a computer to keep track of his plant lists.

When the AEA Geology Group disbanded, the remaining members then joined the FNCV Geology Group, which had the same aims as the AEA Geology Group. John joined the FNCV in 1990 and once a member, he linked his geology with botany, concentrating on the western suburbs, and he became most involved with native grasses and plants and the impact of urban living on remnant grasslands.

At least once a week, or perhaps fortnightly, he would visit the Herbarium to have a plant or seed identified. Sometimes he did not agree with their conclusions and invariably he was correct. He wrote articles on remnant vegetation in *The Victorian Naturalist* and took members of our Club on several excursions in western and northern suburban localities. One article carefully documented a list of plants in the remnant vegetation of the Fawkner Memorial Park (excluding the deliberately planted gardens) where he worked (Vol 109 (3), 1992, pp. 74-79).

A funeral service was held for John at R.C. Corpus Christi Church Glenroy on 27 December 2000. Dorothy Mahler and I attended with Ian Stewart, an FNCV member and cousin of John.

John Stewart's cheery countenance, integrity and faithfulness will be sorely missed by his family and Club members.

Noel Schleiger
1 Astley Street,
Montmorency, Victoria 3094.

Pythons of Australia: a Natural History

by Geordie Torr, illustrated by Eleanor Torr

Publisher: *University of New South Wales Press, 2000. 103 pp. 16 pages with colour plates. RRP $32.95 (incl. GST), paper cover*

Anyone who has wandered into one of the growing number of pet shops selling native wildlife will have realised that pythons are becoming increasingly popular as pets. This popularity is leading to a greater awareness of these intriguing snakes, particularly amongst those of us unfortunate southerners who do not share our local environment with pythons. It is no longer only biologists and keen amateur herpetologists who have an interest in information about the biology and ecology of pythons; now a far wider group of pet-owners want information on these fascinating animals. 'Pythons of Australia' is a text that will appeal to all of these people, as well as students and anyone with an interest in the environment or Australian wildlife.

Geordie Torr is a writer for Australian Geographic magazine, and the skills he employs to popularise science and the environment for this magazine are evident in 'Pythons', with somewhat complex concepts explained in a manner that will be easily understood by all readers. Perhaps more importantly, Torr is a protégé of Professor Richard Shine, arguably Australia's (and one of the world's) foremost authority on snakes. The work of Shine and his students, as well as the extensive research on pythons conducted by Gavin Bedford, forms the basis of most of the information in this book. The work of these researchers provides much recently collected data from which to construct a comprehensive overview of the history, biology and ecology of pythons.

'Pythons of Australia' is one of a series of natural history books that examine Australian native wildlife. The bulk of the other books in the series has tended to target more iconic species (e.g. Kangaroos and Koalas), or those that fit the 'cute and cuddly' profile (e.g. Mountain Pygmy-possum and Little Penguin), although Harold Heatwole's 'Sea Snakes' is an obvious exception. Unlike other books in the series, 'Pythons' provides an overview of the captive care and breeding of pythons, a feature that will undoubtedly give this book broader appeal than others in the series.

The book commences with an examination of the history of Australian pythons, from the fossil record to the discovery of modern pythons, acknowledging that, prior to European incursion, pythons were well known to the aborigines and are a notable feature of aboriginal art. The taxonomy and biogeography of pythons are explored, as well as the striking convergent evolution between the spectacular Green Tree Python of Australia and New Guinea, and the American Tree Boa of South America. The section on biogeography incorrectly states that, within Victoria, pythons are restricted to the more arid regions in the north-west. Two subspecies of *Morelia spilota* occur within Victoria. The Carpet Python occurs along the Murray River from near Walwa in the east, to the border with South Australia in the west, as well as various localities considerably south of the river in the north of the State. The Diamond Python occurs in far east Gippsland. This is a minor criticism, however, as the book must take a broad-brush approach to the subject of species' distribution.

The anatomy and physiology of pythons is then discussed, covering both external and internal anatomy, as well as senses, metabolism, digestion and water relations/excretion. The text is interspersed with some trivial gems, including the fact that the Black-headed Python is able to regenerate its tongue if it is damaged! Many of the complex physiological and experimental concepts in the text are handled admirably by the author, bringing them easily into the realm of the lay reader.

Based largely on data collected during radio-telemetry studies, Chapter 3 covers the behaviour of pythons, but includes

information on locomotion, spatial subdivision and shelter sites. Although infrequently observed, pythons display numerous interesting behavioural traits, ranging from ritualised combat amongst male snakes in the breeding season, to secreting themselves in the ceilings of houses in winter, unknown to most of their human co-tenants! Unfortunately, several of the graphs in this (and other) chapters do not have 'stand alone' explanations of all graphical symbols or axis titles, although the significance of the graphs can be gleaned from the accompanying text.

Chapter 4 covers reproduction and life history, exploring such themes as reproductive behaviour, gestation, incubation, clutch sizes and frequency and hatching, as well as post-hatching traits such as growth, sex ratios and sexual dimorphism. A particularly interesting aspect of python reproductive behaviour is explored in this chapter. Unusually for an ectothermic animal, female pythons are able to generate heat internally to assist in the brooding of eggs. Using a process known as 'shivering thermogenesis' the female uses regular spasmodic muscle contractions to raise her body temperature well above the ambient temperature. She does this whilst coiled around her eggs, transferring her warmth to the eggs and helping to maintain them at a high and stable temperature. In the section on longevity and mortality a range of species that prey on pythons is mentioned, however foxes are not specifically included amongst these. Predation by foxes appears to be one of the major threats to the Carpet Python in Victoria, and is one of the reasons this subspecies is considered threatened in this State.

Food and feeding is covered in Chapter 5, including the types of prey taken by various python species and the methods used to capture these prey. As Torr points out, the ability of pythons to consume relatively enormous prey is 'the stuff of legend' (p. 15), and taking prey up to the size of pigs and wallabies is not uncommon for some larger python species. Most adult pythons prey largely upon birds and mammals (although the Black-headed Python takes few mammals, relying instead on a predominantly reptilian diet), although juveniles of most species tend to eat mainly lizards.

The conservation and management of pythons is discussed in Chapter 6, where Torr points to the dearth of data on the abundance, distribution, ecology and processes threatening many python species. Some species of python are considered locally threatened in certain areas, some subspecies are considered threatened by various state government agencies (such as the Carpet Python in Victoria), and the Rough-scaled Python is known from only three specimens. Like so many other species of native wildlife, the greatest threats to pythons come from habitat destruction and introduced predators, and only the amelioration of these threats will create long-term security for the snakes.

Chapter 7 covers the captive care of pythons, and should make this book particularly attractive to herpetoculturalists and those considering acquiring a python for a pet. The added advantage of appealing to this market is that people keeping pythons will be able to discover so much more about their serpent companions than is offered in most books on the captive care of reptiles. The final section, 'Species accounts' provides a profile of each species, and will allow people with captive pythons to enjoy the wider, natural context of their pets.

'Pythons of Australia' is an attractive book, and a useful addition to the library of biologists, students and both experienced and novice amateur herpetologists and will hopefully stimulate further interest and research into these animals. It contains 34 glossy colour plates, many showing interesting and engaging natural history traits such as feeding and egg laying. Of particular interest is Gavin Bedford's photographs of an albino Olive Python. Typographical errors, whilst present, are few and do little to detract from an interesting, informative and quality text, and I heartily recommend it.

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The Field Naturalists Club of Victoria Inc.

Reg No A0033611X

Established 1880

In which is incorporated the Microscopical Society of Victoria

OBJECTIVES: ***To stimulate interest in natural history and to preserve and protect Australian flora and fauna.***

Membership is open to any person interested in natural history and includes beginners as well as experienced naturalists.

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Members receive *The Victorian Naturalist* and the monthly *Field Nat News* free. The Club organises several monthly meetings (free to all) and excursions (transport costs may be charged). Field work, including botany, mammal and invertebrate surveys, is being done at a number of locations in Victoria, and all members are encouraged to participate.

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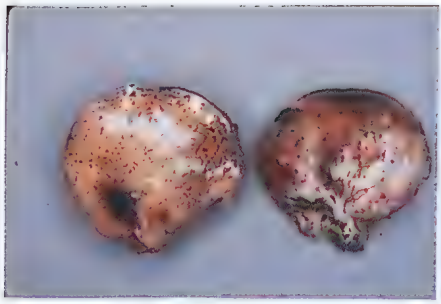
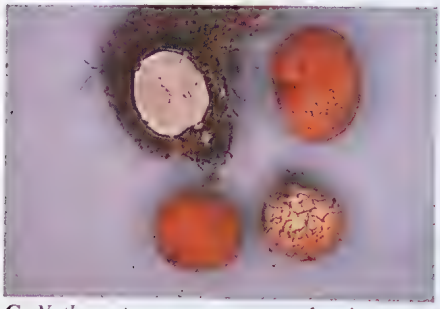
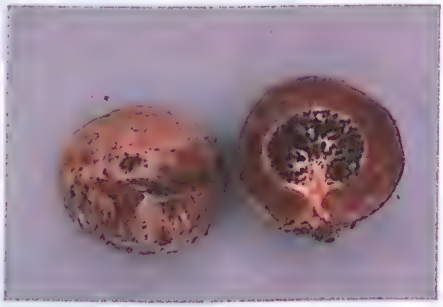


A. General appearance of fruit body of *Zelleromyces* sp.

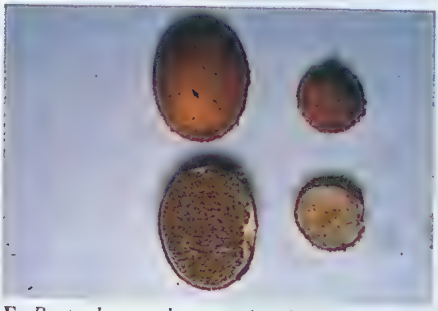
B. General appearance of fruit body of *Macowanites* sp.



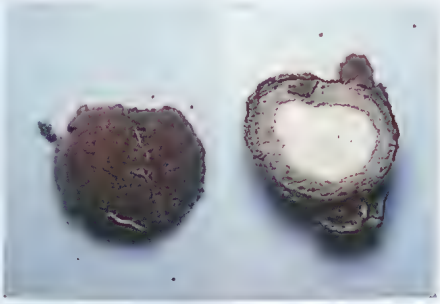
C. *Nothocastoreum cretaceum*, showing powdery interior.



D. *Gelopellis* sp., showing gelatinous interior.

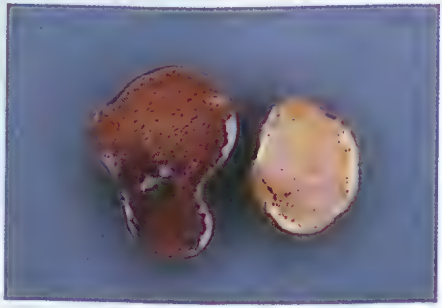


E. *Protoglossum luteum*, showing sponge-like interior.



F. *Mesophellia oleifera*, with central sterile core.

G. *Labyrinthomyces varius*, with solid interior.



H. *Zelleromyces* sp., note latex produced on cutting fruit body.

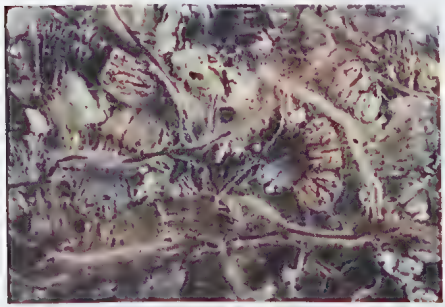
PLATE 1 – all photos by Teresa Lebel

A. *Aleuria aurantiaca*, an ascomycete.

B. *Dermocybe* sp., a basidiomycete.

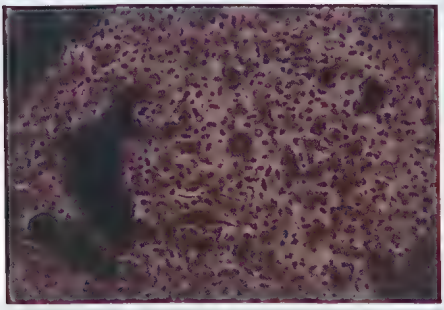
C. *Glomus* sp., a zygomycete (pea-truffle).

D. *Hebeloma aminophilum* or the 'Ghoul fungus', growing amongst the carcass and bones of a dead animal.



E. Mycorrhizal root tips of *Alnus* sp. (Alder) in pot culture.

F. Truffle fruit body pushing through soil, causing soil to be raised.



G. Sample from a ground up faecal pellet of Northern Flying Squirrel showing the large number of different fungal spores present.

H. Truffle fruit body in situ after raking the leaf litter aside.

PLATE 2 – all photos by Teresa Lebel

A. *Cymatoderma elegans*, Bangalee. Photo: Pat Jordan.

B. *Plectania campylospora*, N.S.W. Photo: Pat Jordan.

C. *Vibrissea dura*, Tasmania. Photo: Bruce Fuhrer.

PLATE 3

The Victorian Naturalist

Volume 118 (2) 2001 April

Editor: Merilyn Grey
Assistant Editors: Alistair Evans and Anne Morton

Contributions

Native Truffles of Australia, *by Teresa Lebel* 38

Notes on Fungimap Target Species, *by Tom May* 44

Field Identification, Ecology and Conservation Status of the Red-chested Button-quail *Turnix pyrrhothorax* in Northern Victoria, *by L.E. Conole and R. Mac Nally* 56

Research Report

The Impact of Dieback Disease (*Phytophthora cinnamomi*) on Vegetation Near Mt Stapylton in the Northern Grampians National Park, Western Victoria, *by Julian Di Stefano* 46

Naturalist Notes

Observations of Skink Mating Behaviour, *by Alastair Traill* 58

Observations of Black Snake Feeding, *by Alastair Traill* 59

Book Reviews

Birds of French Island Wetlands, *by Des Quinn and Geoff Lacey, reviewed by Martin O'Brien* 60

Common Australian Fungi: a Bushwalker's Guide, *by Tony Young, reviewed by Rod Barker* 61

Wildflowers of the Brisbane Ranges, *by Clive and Merle Trigg, reviewed by Anne Morton* 62

Field Guide to the Orchids of New South Wales and Victoria, Second Edition, *by Tony Bishop, reviewed by Joan Broadberry* .64

Native Orchids of Southern Australia: A Field Guide, *by David and Barbara Jones, reviewed by Joan Broadberry* 65

Tribute

George Anthony Thomas, B.Sc., Ph.D. (Melb.), *by Neil W. Archbold* 66

ISSN 0042-5184

Cover: *Entoloma virescens*, one of the few blue fungi, Lake Matheson, New Zealand. Photo: Ilma Dunn.

Web page: http://calcite.apana.org.au/fncv/vicnat.html
email: fncv@vicnet.net.au

Native Truffles of Australia

Teresa Lebel[1]

Abstract
Information is presented on the biology, ecology, general taxonomy and diversity of truffles in Australia. A definition of what truffles are is provided, and the importance of their interactions with plants and animals in native forests is summarized. Several hundred species have been described from Australia, yet this is probably a small proportion of the total number of species present. A general guide to where to look for and how to collect truffles is also provided. (*The Victorian Naturalist*, **118** (2), 2001, 38-43.)

Introduction

Truffles (both true and false) do occur in Australia. Several hundred species of truffles have been described, mostly from the higher rainfall, tall forests of coastal regions. The diversity of truffles found in the last century in Australia is comparable to that of Europe, where the level of taxonomic and gastronomic interest has been much higher for several hundred years.

Truffles are fungi which either do not actively discharge their spores and/or have fertile tissue (spore-bearing) which matures in an enclosed, below-ground (hypogeous) or partially exposed (emergent) fruit body. These fungi, which are relatives of the cup fungi and gilled mushrooms, have evolved a spore dispersal strategy that depends on animals and many have strong odours which act as attractants (Castellano *et al.* 1989; Claridge and May 1994; Maser *et al.* 1978; Trappe 1979). Some Australian mammals, such as the Long-footed Potoroo, rely on these fungi as a food resource for a large portion of their diet all year round (Claridge *et al.* 1996). The majority of truffles are thought to form beneficial (mycorrhizal) associations with the roots of many trees and shrubs, acting as buffers against stresses such as diseases and aiding in nutrient cycling and the exchange of nutrients between plants and fungi. The interactions between truffles, plants and animals have implications for management and conservation of all these groups. This article presents information about the biology, ecology, general taxonomy and diversity of truffles in Australia. It also provides a guide to where to look for and how to collect truffles.

[1] National Herbarium of Victoria, Royal Botanic Gardens Melbourne, Birdwood Avenue, South Yarra, Victoria 3141.

What are truffles?

Like mushrooms, truffles are ephemeral fruit bodies that produce spores by which new colonies of the fungus are established. Unlike mushrooms which fruit aboveground, truffles typically have fruit bodies that mature below ground. The spore-bearing tissue is usually completely enclosed by an outer covering (called a peridium) or may be exposed to some degree, but the spores are retained (i.e. no spore print is obtainable as it is in mushrooms) until the fruit body decomposes or is eaten. Truffles are quite variable in size, shape, colour, texture, odour, overall appearance and microscopic features. In size, truffles range from a five cent piece to larger than a tennis ball, and can weigh over 400 grams. The fruit bodies mostly look like small pebbles or potatoes (Plate 1A) but can also have the appearance of an aborted mushroom (Plate 1B). A full range of colour from pure white, flesh tones, drab browns and yellows to brilliant orange, green, red, purple or blue is visible on the exterior and interior of fruit bodies of different species. When cut in half truffles may be powdery (Plate 1C), gelatinous (Plate 1D), sponge-like (Plate 1E), or have a central core of sterile tissue (Plate 1F), or solid with a marbled appearance (Plate 1G). A few truffles produce a milky latex when cut or injured (Plate 1H) and some change colour. Most Australian native truffles have a chambered appearance in cross-section.

The truffle fruit body form has arisen several times in three quite different lineages of fungi: the ascomycetes (cup fungi and allies - Plate 2A), basidiomycetes (mushrooms, puffballs, and bracket fungi - Plate 2B), and zygomycetes (Pea-truffles - Plate 2C). This diversity of origin is apparent in the variety of colours, textures,

odours and overall structure of the fruit bodies of truffles. Many truffles can be clearly recognised as related to specific genera of fungi which have above-ground fruit bodies. These relationships are based on the similarity of microscopic characters such as spore ornamentation, or shape and type of sterile cells. So, *Tuber* (truffle) and *Peziza* (cup fungi) have similar microcharacters as do *Hydnangium* (truffle) and *Laccaria* (mushroom), *Protoglossum* (truffle) and *Cortinarius* (mushroom), and *Rhizopogon* (truffle) and *Suillus* (bolete) (Bruns *et al.* 1989; Trappe 1979). These relationships have been confirmed from studies of DNA sequences; however, many other hypothesised relationships remain to be tested using molecular tools. A few taxa defy placement in known groups and are placed in their own families and/or orders, e.g. Mesophelliaceae, Elaphomycetales.

The three main groups of truffles can be easily distinguished by differences in how the spores are formed at the microscopic level. Ascomycetes produce up to eight spores inside globose to cylindric sac-like cells called asci (Fig. 1). Basidiomycetes produce up to eight spores on the outside of club-shaped cells called basidia (Fig. 2), and zygomycetes produce large spores at the end of hyphae. It is difficult for the casual observer to tell the different groups of truffles apart on sight. However, definite macroscopic differences are detectable by the experienced eye (Trappe and Castellano 1991).

Terminology

Many different terms have been used to describe truffles. All the terms describe a particular fruit body form, with partially or completely enclosed fertile tissue, and may be correctly applied to a subset of all the fungi that have this habit. The term 'truffle' is sometimes restricted to the prized edible fruit bodies of the genus *Tuber*, or to ascomycete truffles (the true truffles), with the basidiomycete and zygomycete truffles then referred to as 'false truffles'. Another term used for this group is 'sequestrate' in reference to the spore-producing tissue remaining enclosed even at maturity (Kendrick 1992). For simplicity, in this paper I use the term truffle to encompass the true and false truffles.

Nutrition, Structure and Habit

Macrofungi are made up of extremely fine branching tubes called hyphae (singular hypha) which make up the diffuse, perennial body or mycelium of the fungus in the soil as well as the fruit body of the mushroom or truffle. The hyphal walls are composed of chitin, which is indigestible to almost all animals (this is why eating a large helping of mushrooms may give some people indigestion). Unlike plants, fungi have no means of making their own food, instead gaining nutrition either from living organisms or from their remains after death. Fungi have a large array of enzymes that can digest some recalcitrant substrates such as chitin (insects and other fungi), keratin (hair, skin, horn, feathers), cellulose (plant material) and lignin (wood) (Plate 2D). This ability to use a range of substrates makes the fungi extremely important in recycling of nutrients in ecosystems.

The majority of truffles form mycorrhizae, a close and mutually beneficial association with plant roots (Harley and

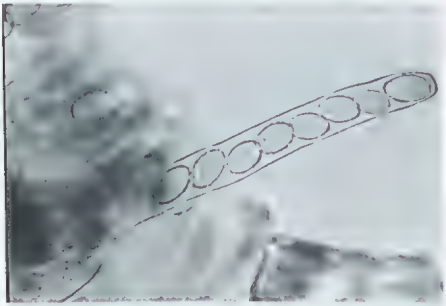


Fig. 1. Location of spores in ascomycetes. Ascus with eight ascospores inside. Photo: Teresa Lebel.

Fig. 2. Location of spores in basidiomycetes. Basidium with single spore attached externally to sterigmata. Photo: Teresa Lebel.

Smith 1983). Indeed, many plants depend on mycorrhizal fungi for seedling establishment and growth, and generally associate with many species of fungi. The fungus forms a tight weft of hyphae around the fine lateral root tips of the plant (like a sock) and penetrates between the outermost cells of the root, without apparently harming the plant cells. In this partnership the plant obtains water and nutrients from the fungus and the fungus gains nutrients and compounds from the plant that it cannot produce itself. The physical barrier presented by the fungal hyphae on the root tips, and the increased nutrient capabilities of the root system in this association, provide a buffer against stresses such as drought and disease (Plate 2E). In Australia most forest trees and many shrubs form mycorrhizal associations, especially from the genera *Leptospermum, Eucalyptus*, *Allocasuarina*, *Acacia, Gastrolobium* and *Nothofagus* (Brundrett *et al.* 1996). The majority of Australian truffles appear to be relatively non-selective in terms of the plants that they associate with, for example *Hydnangium carneum* which appears to form mycorrhizal associations with a large number of different *Eucalyptus* and *Leptospermum* species.

Truffles are generally greatest in number and variety near the interface between the litter layer and the hard subsoil layer, i.e. within the top five centimetres of leaf litter and soil. A few, including species of *Tuber, Elaphomyces*, and members of the Mesophelliaceae, fruit more deeply in the soil; some have been found at depths of nearly a metre. Where the soil is compacted, as in heavily-used camp grounds, picnic areas or along abandoned roads, truffles often fruit on the soil surface or close enough that they hump up or sometimes crack the soil (Plate 2F). The mycelium is present in the soil all year; all that is required is the right trigger for fruit bodies to be formed. Truffles may fruit at any time of the year; most species fruit in only one season, but others appear more or less continuously throughout the growing season. In temperate regions, spring and autumn usually produce a flush of truffle fruit bodies, which generally coincides with maximum fruiting of mushrooms. As with many mushrooms, the diversity and extent of fruiting appears to be largely affected by rainfall and temperature. However, the hypogeous nature of the fruit body means that truffles are protected a little more from short droughts or cold snaps and so may be found for longer periods. Ascomycete truffles are slow growing, taking many months to mature and then slowly decay. In contrast, many basidiomycete truffles tend to be ephemeral; the fruit bodies form, expand and mature and decay over a few weeks. Zygomycete truffles may be found all year round.

Diversity and Distribution

Truffles occur worldwide in a diversity of habitats, wherever suitable plant associates grow. Australia has one of the highest levels of diversity of truffles in the world: 83 genera and 294 species are currently known, and several more genera and species are currently being described. Information from recent studies in Australia, both taxonomic revisions of specific genera or groups and ecological surveys of different habitats, suggests that between 12-24% of species are known (Lebel 1998; Claridge *et al.* 2000 a, b). On that basis, between 1250 and 2450 species may occur in Australia. More than 35% of Australian truffle genera and 95% of species are endemic (Bougher and Lebel *in press*), though a lack of collections from other southern hemisphere countries such as Africa and South America may cause some overestimation of endemism.

Although extensive collections have been made in Australia and New Zealand in the last eight years, much of the data should be considered preliminary as many areas have not been sampled, seasonal data is often lacking, and the area sampled at each site in short, opportunistic surveys is generally quite small. Considerable diversity can be found on relatively small, localised sites if surveys are conducted more than once in a year or over several years, e.g. Claridge *et al.* (2000a) collected truffle fungi twice in a 14 ha area and found 209 species of which 153 were undescribed. Knowledge of the diversity and ecology of truffle fungi is limited, primarily because these fungi can only be reliably identified by their fruit bodies, which are generally ephemeral,

seasonally abundant, patchily distributed and often hypogeal, that is, time-consuming to find. A single sampling will 'pick up' only a fraction of the species present at a site, and recording a reasonable proportion requires repeated sampling at regular intervals throughout the year and over several years (Claridge *et al.* 2000 a, b; Colgan *et al.* 1999). Sampling of truffle fungi is further complicated by the high proportion of undescribed species and lack of keys and descriptions, making identification difficult.

Mycophagy

As the fruit bodies of truffles typically mature below ground they must be removed from the soil if their spores are to be dispersed. This is generally accomplished by insects and other animals which rely on the truffles as a food resource (Fig. 3). Many of the truffles produce strong odours which act as attractants when they are mature, ensuring the fungus has its spores dispersed. The recently re-discovered Gilberts Potoroo from Western Australia and the Long-Footed Potoroo from eastern Australia rely on fungi year round for up to 90% of their diet (Claridge *et al.* 1996). Examination of faecal pellets shows that the animals are finding a greater diversity of truffle species (based on spore types) than is apparent from fruit body collections made in the same areas (Plate 2G). Other Australian animals such as native mice and rats may eat significant amounts of truffles, especially in autumn (Claridge and May 1994).

The edibility of Australian truffles for human consumption is largely untested. Aboriginal peoples are known to use several types of truffles for food, medicine and other purposes (Kalotas 1996). Anecdotal evidence of a very few cases of upset stomachs exists in the literature, but these are usually cases of mis-identification of puffballs. Only a few of the several hundred species of truffles are considered delicacies, and all of these are native to the Northern Hemisphere. The esteemed edible truffles, species of *Tuber*, have been introduced to Australia on the roots of oaks and chestnuts in various commercial ventures in New Zealand and Tasmania (Hall *et al.* 1998). However, none of the Australian native truffles examined for taxonomic purposes so far has the same combination of smell, taste and texture as the 'gourmet' truffles of France and Italy (Fig. 4).

Collecting truffles

Though abundant in Australia, truffles are often overlooked because of the hypogeous nature of the fruit body, and the appearance of some as aborted mushrooms. A fork or a rake is the most important tool for unearthing truffles. A four-tined garden fork with the handle cut to about one metre long is the most comfortable, as it requires less stooping and covers more area than a smaller type of rake. The most likely location for truffles is around the roots of suitable hosts. If searching after the first heavy rains of autumn or during summer periods, the canopy drip-line or base of the trunk are good places to start your search. At any time of year, signs of animal activity, such as digs or turned-over soil and leaf litter are important clues to truffle production. Small mammals usually unearth truffles one at a time, leaving a small pit; they will dig up only the more mature truffles, leaving the less mature to ripen. Hence, the small pits indicate likely places to rake. Other animals

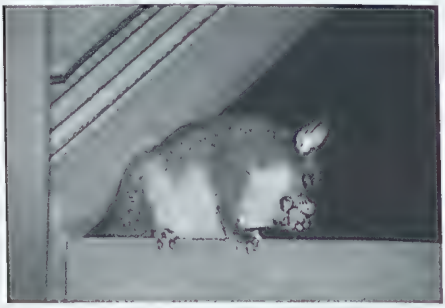


Fig. 3. Possum eating a truffle offered to it. Photo: Teresa Lebel.

Fig. 4. Italian white truffles for sale in a market in the Alba region, Italy. Photo: Teresa Lebel.

such as Lyrebirds turn over large amounts of leaf litter, and it can be quite profitable to follow as the bird actively 'truffles' for you. Random searching can also provide fine collections. Generally a heavy ground cover of grasses or small shrubs is not conducive to high abundance or diversity of truffles.

Choose a spot, then gently rake the litter aside and inspect the exposed humus for specimens. Then rake the humus down to mineral soil while watching for truffles as the soil is turned over (Plate 2H). If there is any suggestion of a mycelial network, continue raking a little deeper or extend the dig. Once a specimen is found, note the depth and kind of material in which it is growing; truffles are often gregarious, and many additional specimens may be nearby in the same substrate or mycelial system. When raking is complete, the soil and litter should be redistributed onto the original spot. More than one species may fruit in a spot, so take notes for each specimen that appears different from the others, and place in separate wax or paper bags or wrap in wax paper. Do not use plastic, as it is a good incubator for bacteria and retains moisture (specimens kept in plastic bags on a warm day rapidly become a slimy mess).

While the specimen is fresh, write notes on its colour and odour, whether a latex is exuded from a cut surface, and whether the specimen changes colour when either cut or bruised (press your finger firmly on the surface, but do not rub; if no immediate colour change occurs, recheck the specimen in 10 minutes). The date, locality (including map reference or latitude-longitude), collector, associated plants and any interesting site information should be noted. A large number of new species and genera of truffles have been found in Australia in the last few years and many more are likely to be encountered. Collections without locality, date and comprehensive notes made at the time of collection may be interesting but are of little value for increasing our knowledge of truffle distributions or diversity. Description of characters made while the truffle is fresh are important in the identification of specimens, and will greatly enhance the value of a collection if it becomes the type of a new species. Each specimen should be sliced in half vertically, through the centre; most specimens will have an apparent point of attachment, so use this to decide where to cut. Many species resemble each other on the surface but differ in the interior. Truffles also resemble seed pods, dried chewing gum, clods of dirt, pebbles, and mushroom buttons. Slicing the specimen in half will allow you to confirm that the collection is at least fungal! For several reasons, well-dried specimens are more useful and easier to maintain than those preserved in liquid. Specimens in good condition can be stored in the fridge for several days if necessary. A food dryer or dehydrator set at 30°C works well to air dry specimens.

Conclusion

We have little knowledge of the potential rarity of truffles. The lack of collections from many habitats and regions in Victoria and other parts of Australia is a problem that needs to be addressed. In the case of truffles this is further exacerbated by the general difficulty in collecting specimens. The high likelihood of finding new species and possibly genera, and the difficulties of collecting, makes the search for truffles an exciting, interesting, and sometimes frustrating endeavour. I hope to address the lack of readily available keys and other identification tools for the truffles of Australia by writing various articles in the *Australasian Mycologist*, *The Victorian Naturalist* and other journals, and also providing a guide to the truffles of eastern Australia in the next few years.

If you are interested in finding out more about collecting and identifying truffles, or helping with ongoing research, please contact the author.

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Rules for Hunting Truffles

(a) always seek the landowners' permission

(b) obtain a permit to collect if required (check if you are not sure)

(c) be careful that you do not disturb the root systems of associated plants

(d) replace all disturbed soil and leaf litter

(e) always wash your truffle-fork with water or a weak bleach solution if you are truffling in different areas (this will help reduce the spread of pathogenic fungi)

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Notes on Fungimap Target Species

Tom May[1]

Fungimap

Fungimap is a mapping scheme which records distribution and ecological information for 100 distinctive species of Australian fungi (see http://calcite.apana.org.au/fungimap/). Many of the target species are illustrated in Fuhrer (1993) and Bougher and Syme (1998), and in other field guides or sources such as the *Fungi of Australia* series (vols 1A and 1B) and the 'Australian Cryptogams' calendars produced by Judith Curnow and Heino Lepp. Indeed, many of the target species were chosen because they were relatively common, and good illustrations were already available.

Most target species have turned out to have broad distributions, often occurring in eastern and south-western Australia, or else widely through the interior. Some targets, however, were selected because they were thought to be rare or restricted in distribution, with the hope that Fungimap records could confirm this status, and lead to listing of species on state and commonwealth endangered species schedules. Even a lack of records would be useful, since, in comparison to the many hundreds of records of each common species, this would show that the species were indeed rare. Unfortunately, most of the rarer species were not illustrated in the popular mycological literature, so a lack of records could be due to recorders not being familiar with the species. Inclusion of a colour section to this issue of *The Victorian Naturalist* provides the opportunity to illustrate some of the rarer or more unusual target species (some for the first time in colour), as well as a few common species that have been omitted from recent field guides. Species which seem particularly rare are: *Banksiamyces macrocarpus*, *Craterellus cornucopioides*, *Hypocreopsis* sp., *Nyctalis mirabilis* and *Rozites roseolilacina*.

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Target species

There are few blue fungi, and none with the tone and richness of colour of ***Entoloma virescens*** (front cover), whose conical cap (to 50 mm diam.) and stem are uniformly an intense sky blue.

Cymatoderma elegans (Plate 3A) is a large (up to 30 cm diam.), stalked fungus which grows on wood, with the spores produced on the smooth or shallowly-ridged underside of the funnel-shaped cap.

The black cups of ***Plectania campylospora*** (Plate 3B) are up to 50 mm in diameter, and are found on fallen wood.

The stalked pinkish or pinkish brown globular heads of ***Vibrissea dura*** (Plate 3C) occur on fallen wood. Some slime moulds produce stalked globular spore masses, but these are usually smaller on thinner stalks, and are soft and easily crushed. In *V. dura* the head is up to 7 mm diam. and the fruit body is up to 30 mm high.

Nyctalis mirabilis (Plate 4A) is a gilled fungus which produces fruit bodies upon the fruit bodies of members of the Russulaceae (probably species of *Russula*). The cap is up to 30 mm diam. This is Australia's only 'toadstool upon a toadstool'. Known only from a few sites in Cool Temperate Rainforest in Victoria and in Tasmania.

Ping-pong bats is an apt common name for the diminutive ***Dictyopanus pusillus*** (Plate 4B). This is a common species which grows on wood, often occurring in massed colonies. Caps are about 5 mm broad. Although pored, it is closely related to the gilled *Panellus stypticus*.

Among the stalked puffballs, ***Battarraea stevenii*** (Plate 4C) is distinguished by the cap which falls to the ground when the orange-brown spore mass matures. The weathered stalk (up to 35 cm high) resembles a stick from a paperbark.

One of the rarest fungi in Australia is an undescribed species of ***Hypocreopsis*** (Plate 4D) found at a few near-coastal sites on the Mornington Peninsula and west Gippsland. The lobed, brown fruit body

clasps branches. The fruit bodies are up to 60 mm across, with individual lobes about 2 mm broad.

Anthurus archeri (Plate 5A) is often confused with the similarly-hued (and malodorous) *Aseroe rubra*, which has bifid arms. The illustrated *Anthurus* is interesting in having one (only) of the arms branched. Arms vary from 30 to 70 mm long.

Compared to the common *Calostoma fuscum*, the rainforest-loving ***Calostoma rodwayi*** (Plate 5B) is smaller and the outer layer does not fall away as a whole cap, but remains as scattered gelatinous scales, and sometimes as a shield peeling away around the scarlet mouth. The peridium in *C. fuscum* is up to 30 mm diam., whereas in *C. rodwayi* it is no more than about 10 mm diam.

The deadly Death Cap ***Amanita phalloides*** (Plate 6A) is an unwelcome immigrant, found under exotic oaks, and invading native *Nothofagus* forests. Distinguished by the yellowish or greenish caps (to 10 cm diam.) and the volva (membranous cup) at the base of the stem.

The several species of the genus *Rozites* occurring in Australia differ from *Cortinarius* in the possession of a membranous ring. ***Rozites roseolilacina*** (Plate 6B) has a dry, pinkish mauve cap (to 11 cm diam.). It is a very rare species in Victoria (known only from the Grampians), and is known otherwise from a few sites in Tasmania.

The stalked cup-fungus ***Aleuria rhenana*** (back cover A) is not a current target species, but is included to allow comparison against the similarly coloured *Cookeina tricholoma*. The latter grows on wood in tropical areas, and has a fringe of long hairs around the margin of the cup. *A. rhenana* is up to 25 mm diam. and *C. tricholoma* reaches 20 mm diam.

The Crinoline Fungus ***Dictyophora indusiata*** (back cover B) has a yellow cap, initially covered with the slimy spore mass, and a white, lacy frill. The fruit body is up to 20 cm tall.

Banksiamyces are found only on *Banksia*. The relatively large discs (to 25 mm across) of ***Banksiamyces macrocarpus*** (back cover C) are known only from *Banksia spinulosa*.

Preferring Cool Temperate Rainforest, ***Craterellus cornucopioides*** (back cover D) produces clusters of vase-shaped fruit bodies, with spores produced on the dark exterior surface of the 'vase'. Individual fruit bodies are up to 60 mm high.

Fungimap CD-ROM

A CD-ROM compendium of the Fungimap target species will be available in April 2001. The CD-ROM contains numerous photographs (including many of those shown here), along with maps of all species. For many of the target species, multiple illustrations are provided, to show variation and changes during development. All text and photos for the CD-ROM, and the considerable time of Ian Bell in design and programming, have been donated. The CD-ROM will be updated, and expanded to include further targets. Further photos are always welcome.

Acknowledgements

Merilyn Grey and Anne Morton suggested that additional fungi illustrations be included, and are thanked for their encouragement and assistance. Special thanks are due to the photographers who provided the illustrations: Ilma Dunn, Bruce Fuhrer, Sheila Houghton, Virgil Hubregtse, Pat Jordan, Ian McCann, Margery Smith and Anneke Veenstra-Quah.

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Fungimap Inaugural National Conference

22-26 June 2001

Denmark, Western Australia

The Fungimap conference is aimed at Fungimap volunteers, many of whom are relatively new to the study of fungi. There will be field trips to ancient eucalypt forests, coastal heath and woodlands. Workshops will be held on using fungi keys, fungi identification, documentation, preservation and storing fungi for regional and state herbaria and conducting surveys of fungi.

Enquiries to Fungimap Conference, Denmark Environment Centre, PO Box 142, Denmark WA 6333 Phone 08 9848 1644 day, 08 9848 1293 ah. email fungidenmarkwa@wn.com.au

The Impact of Dieback Disease (*Phytophthora cinnamomi*) on Vegetation Near Mt Stapylton in the Northern Grampians National Park, Western Victoria

Julian Di Stefano[1]

Abstract

Phytophthora cinnamomi Rands is a soil borne pathogen that leads to the decline of many plant species across Australia. In this study, presence, cover-abundance and health were recorded for plant species within healthy, transitional and diseased zones in a dry sclerophyll forest near Mt. Staplyton in the north western section of the Grampians National Park, western Victoria. The data were subjected to non-metric multidimensional scaling (NMDS) analysis, and a change in the distribution and abundance of plant species between healthy, transitional and diseased zones was observed. A seed/fungus test using susceptible *Lupinus alba* seedlings was performed, and the results are consistent with the hypothesis that *P. cinnamomi* caused the dieback observed at the study site. The vegetation changes observed represent a transition from healthy *Eucalyptus baxteri* forest with a low heathy understorey to a more open forest with many dead trees and an increased number of sedge and grass species. This transition is expressed as a reduction in biodiversity, density and plant health within diseased and transitional zones, although no effect on vegetative cover was detected. Options for the management of *P. cinnamomi* are also discussed. (*The Victorian Naturalist* **118** (2), 2001, 46-55.)

Introduction

Plant pathogens are an established part of plant communities world-wide. In many regions, they play an important role in the patterns and processes of change that occur within forest ecosystems (Castello *et al.* 1995). However, in some forest ecosystems, plant pathogens may have a destructive impact. This is the case in Australia, where the fungus *Phytophthora cinnamomi* Rands has caused significant ecological damage since its introduction in the early part of the nineteenth century (Bridgewater and Edgar 1994; Barker *et al.* 1996). Over time, infection by *P. cinnamomi* may result in significant changes in the structure and function of forest floral communities (Wills 1993; Wills and Keighery 1994) as well as affecting the distribution and abundance of both vertebrate (Wilson *et al.* 1990; Wilson *et al.* 1994; Newell 1998) and invertebrate (Postle *et al.* 1986; Newell 1997) fauna.

P. cinnamomi is a soil-borne fungus belonging to the class Oomycota. It exists in the form of mycelium or chlamydospores in root and decaying plant tissue (Dell and Malajczuk 1989). Both soil temperature and soil moisture limit the distribution and abundance of *P. cinnamomi*. Optimum soil temperatures for pathogenic activity are between 22°C and 27°C, although infection still occurs in soils warmer than 14°C (Dell and Malajczuk 1989). Barker *et al.* (1996) suggest that in Tasmania, the severity of pathogenic activity is reduced in regions receiving less than 600 mm of rainfall per year. Dispersal occurs when zoospores are transported by laterally moving subsurface water, although surface runoff also has dispersal potential (Kinal *et al.* 1993). Dispersal is also enhanced by human activities. Transportation of infected soil (for road construction, for example), has led to the introduction of *P. cinnamomi* to previously unaffected areas (Wills 1993).

In the Grampians National Park, western Victoria, areas infected by *P. cinnamomi* were first observed in the early 1970s (Kennedy and Weste 1986). More recently, a new section of forest displaying characteristics consistent with *P. cinnamomi* infection has been identified within the park, and this area provided the site for the current study. The major objective of the present study is to identify patterns of vegetation change between healthy and infected regions. A secondary objective is to discuss the suitability of current and proposed management strategies for controlling *P. cinnamomi* in native forest areas.

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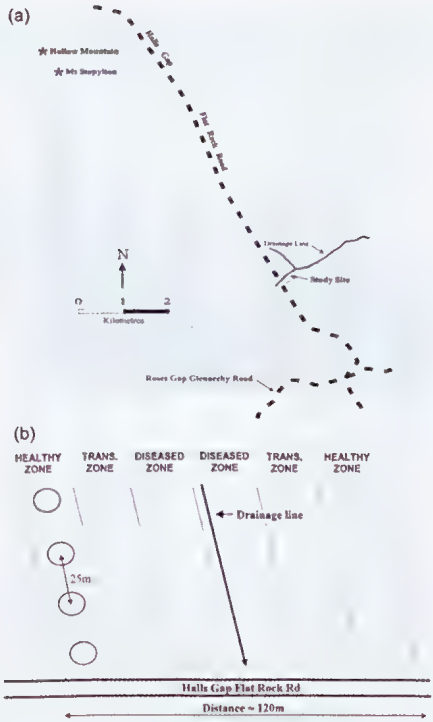

Fig. 1. Study site (a) and experimental design (b). In the experimental design diagram circles represent plots. The area adjacent to the drainage line appeared to be infected by *Phytophthora cinnamomi.*

Methods

Study Area

This study was conducted in the Grampians National Park, western Victoria. The National Park covers 167 000 ha and is noted for the diversity and abundance of flora within it (Kennedy and Weste 1986).

The study site is near Mt. Stapylton in the north-west region of the National Park (Fig. 1a). The region receives around 645 mm of rainfall annually, most of which falls in winter, and is characterised by skeletal, sandy soil with rocky shallow podzols (Sibley 1967). Surrounding healthy vegetation is dominated by *Eucalyptus baxteri*, with a low heathy understorey. Sandstone and mudstone cliffs rise up to the north east of the site. The site has an elevation of 190-200 m and is on a gentle slope (gradient < 5°) with a westerly aspect. The site has a drainage line running through its centre and the strip of forest parallel to the drainage line was believed to be infected by *P. cinnamomi*, as dead and dying *E. baxteri* trees were evident.

Field Work

The sampling program followed a random-sited systematic design. Patterns of vegetation change were investigated by recording the presence, cover-abundance and health of plant species in healthy, transitional and diseased zones. Each zone was divided into two sub-zones, both containing four circular 100 m^2 plots, with 25 metres separating the centre of each plot (Fig. 1b). Vegetation cover was measured using the semi-quantitative Braun-Blanquet cover-abundance scale (Mueller-Dombois and Ellenberg 1974). Species health was measured using a forest health index with a scale between one (healthy) and five (dead).

Laboratory Work

Pre germinated Lupin seedlings (*Lupinus alba*, known to be sensitive to *P. cinnamomi*) were grown in soil samples from the field in order to confirm the presence of a soil pathogen at the study site. Seeds were grown for three weeks in clear plastic, gauze covered containers containing a soil slurry made from 50 g of soil and 100 ml of distilled water. Four seedlings were grown in every container. Twenty four containers were used, one for each plot. After one week and three weeks, seedlings in each container were identified as being either healthy, unhealthy or dead. Healthy, unhealthy and dead seedlings were identified visually.

Data Analysis

Unstandardised semi-quantitative floristic data were used to determine the ecological distance between plots by using the Bray-Curtis dissimilarity coefficient. The resulting matrix was subjected to non-metric multidimensional scaling (NMDS) analysis as described by Kent and Coker (1992) using the DECODA software package (Minchin 1987). Species that were present in only one plot were excluded from the analysis, as they distorted results by making plots unique. Analysis was performed in one to three dimensions, from ten random starts. The two dimensional solution (stress = 0.15) was chosen, as additional dimensions did not provide sig-

nificantly more ecological information.

Null hypotheses about the number of healthy *L. alba* seedlings three weeks after sowing, mean species richness per plot and mean cover per plot were tested using the general analysis of variance (ANOVA) procedure in GENSTAT. All null hypotheses predicted that variables would not differ between healthy, transitional and diseased zones. Where necessary, post-hoc tests were conducted using the Least Significant Difference method ($\alpha = 0.05$). All data were tested for normality and homogeneity of variance using graphical methods.

Results

Seed/fungus Test

Lupinus alba seedlings were all healthy after one week of growth. After three weeks, the number of healthy seedlings growing in soil from different zones was found to differ significantly $F(2, 69) = 48.94$, $P = < 0.001$. Subsequent post-hoc tests revealed that a significant difference between the number of healthy seedlings existed between all three zones. As expected, the greatest number of healthy seedlings were found growing in soil from the healthy zone and the smallest number of healthy seedlings were found growing in soil from the diseased zone. These results are consistent with the hypothesis that the diseased zone is infected with *P. cinnamomi,* as *L. alba* seedlings are known to be susceptible to this fungus.

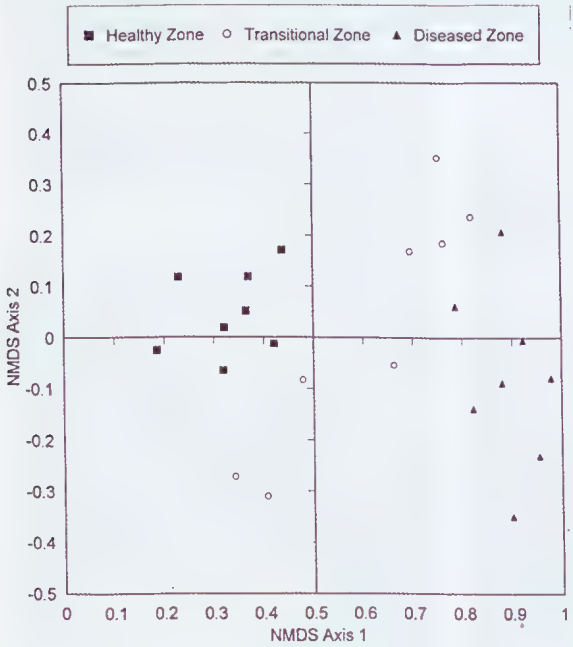

Fig. 2. NMDS ordination of vegetation data.

NMDS Ordination

The NMDS ordination (Fig. 2) shows that the data from healthy, transitional and diseased zones are separated most significantly along Axis 1. The substantial separation between healthy and diseased plots that can be observed along this axis suggests that there is a discernible difference in the structure of the vegetation between healthy and diseased zones.

Floristic Data

A complete list of the families (n = 25) and species (n = 73) within the whole study site can be found in Table 1. Table 1 also shows the frequency with which each species was found in the healthy, transitional and diseased zones, and the response of each plant species to *P. cinnamomi.* Species have been grouped into three response types on the basis of their frequency in each zone:

(a) Susceptible – species that existed in the healthy zone and were rare or absent in transitional and diseased zones.

(b) Resistant – species that were absent or rare in the healthy zone but relatively common in the transitional and diseased zones.

(c) Fluctuating – species that retained similar levels of cover and abundance within each zone.

Family Richness

The number of species within major families is displayed in Fig. 3. Major families were defined as those containing at least two species in at least one of the three zones. These data show that most major families (11 of 13) are represented in all three zones. Moreover, the number of major families represented in each zone changes little, with healthy, transitional and diseased zones containing

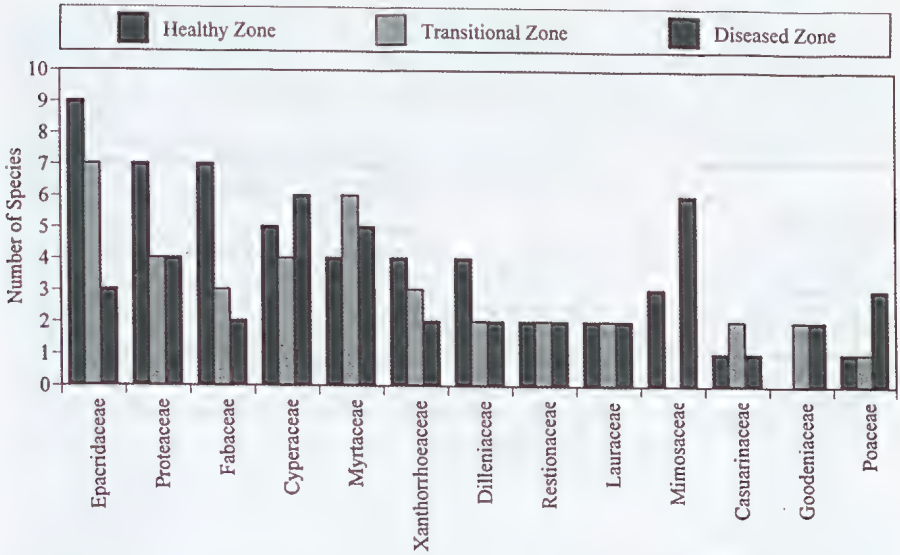

Fig. 3. Plant families that contain two or more species in at least one of the healthy, transitional or diseased zones at the study site.

12, 12 and 13 different families respectively. Nevertheless, the number of species within some families (especially Epacridaceae, Proteaceae and Fabaceae) is much higher in the healthy zone than in the diseased zone.

Species Richness and Cover

Analysis of variance showed that the number of species per plot differed significantly between healthy, transitional and diseased zones: F (2, 21) = 20.65, $P <$ 0.001. Post-hoc tests showed that the number of species per plot in the healthy zone was significantly higher than the number of species per plot in the transitional and diseased zones, but that there was no difference in the number of species per plot between the latter two zones. In addition, the total number of species observed was higher in healthy zones (55 species) than in transitional (46 species) or diseased (50 species) zones. Cover (measured as mean cover per plot) was not found to be significantly different between zones.

Responses of Individual Species to P. cinnamomi

General trends of vegetation change may disguise fluctuations occurring at the species level. Figs 4 and 5 show how the mean cover scores of eight different species changed between healthy, transitional and diseased zones.

In Fig. 4, the mean cover scores for two fluctuating species, *Leptospermum myrsinoides* and *Lepidobulus drapeticoleus*, remain relatively unchanged throughout the three zones. Although the cover score for *L. myrsinoides* fell in the diseased zone, the level of cover was still relatively high (cover = 1.25). The responses of three susceptible species, *E. baxteri*, *Xanthorrhoea australis* and *Isopogon ceratophyllus* are also shown in Fig. 4. It is clear that their cover is much higher in the healthy zone than in the transitional and diseased zones. In contrast, Fig. 5 shows the responses of three resistant species, *Hypolaena fastigiata*, *Hakea rostrata* and *Lepidosperma laterale*. These species show a clear trend of higher cover in the transitional and diseased zones.

Discussion

The NMDS ordination shows that the vegetation structure within the study site is heterogeneous. Based on the presence, cover-abundance and health data used in the analysis, vegetation structure differed between healthy, transitional and diseased zones, with the largest difference being between healthy and diseased zones (Fig. 2).

Table 1. A complete list of families and species found within healthy, transitional and diseased zones. The numbers in this table represent the frequency with which a species was identified in a particular zone (maximum frequency = 8). The last column, Species Status, indicates whether the species is susceptible to *P. cinnamomi* (S), resistant (R) or fluctuating (F) based on the frequency data collected in this study. The '?' represents a lack of data and * denotes species that were prolific, but very unhealthy, in the diseased zone.

Families and Species	Common Names	Healthy Zone	Transitional Zone	Diseased Zone	Species Status
Dicotyledons					
Apiaceae					
Hydrocotyle spp.	Pennyworts	0	0	2	R
Asteraceae					
Helichrysum baxteri	White Everlasting	0	0	2	R
Casuarinaceae					
Casuarina muellerana	Slaty She-oak	0	1	0	?
C. paludosa	Scrub She-oak	7	3	1	S
Dilleniaceae					
Hibbertia fasciculata	Bundled Guinea-flower	8	2	2	S
H. sericea	Silky Guinea-flower	1	0	0	?
H. stricta	Erect Guinea-flower	3	1	7	R
H. virgata	Twiggy Guinea-flower	4	0	0	S
Droseraceae					
Drosera whittakeri	Scented Sundew	0	0	1	?
Epacridaceae					
Astroloma conostephoides	Flame Heath	8	3	0	S
A. humifusum	Cranberry Heath	0	0	1	?
A. pinifolium	Pine Heath	8	4	0	S
Brachyloma daphnoides	Daphne Heath	7	1	0	S
Epacris impressa	Common Heath	3	1	0	S
Leucopogon ericoides	Pink Beard-heath	1	0	0	?
L. glacialis	Twisted Beard-heath	7	2	1	S
L. rufus	Ruddy Beard-heath	2	0	0	S
L. virgatus	Common Beard-heath	4	3	3	F
Monotoca scoparia	Prickly Broom-heath	4	1	0	S
Euphorbiaceae					
Phyllanthus hirtellus	Thyme Spurge	3	1	5	F
Fabaceae					
Daviesia brevifolia	Leafless Bitter-pea	5	0	0	S
Dillwynia glaberrima	Smooth Parrot-pea	7	2	2	S
D. sericea	Showy Parrot-pea	5	3	2	S?
Hovea heterophylla	Common Hovea	2	0	0	S
Phylotta pleurandroides	Heathy Phylotta	2	0	0	S
Platylobium obtusangulum	Common Flat-pea	8	2	3	S
Pultenaea spp.	Bush Peas	1	3	1	?
Goodeniaceae					
Dampiera lanceolata	Groved Dampiera	0	0	1	?
Goodenia geniculata	Bent Goodenia	4	2	2	F?
Lauraceae					
Cassytha glabella	Slender Dodder-laurel	6	6	5	F
C. pubescens	Downy Dodder-laurel	8	6	6	F
Mimosaceae					
Acacia longifolia	Sallow Wattle	0	0	1	?
A. mitchellii	Mitchell's Wattle	1	0	1	?
A. myrtifolia	Myrtle Wattle	0	0	2	R
A. pycnantha	Golden Wattle	1	2	3	R?
A. ulicifolia	Heath Wattle	2	2	1	?
Myrtaceae					
Calytrix tetragona	Fringe-myrtle	5	4	6	F
*Eucalyptus baxteri**	Brown Stringybark	8	8	6	S
Leptospermum juniperinum	Prickly Tea-tree	0	2	3	R
L. myrsinoides	Heath Tea-tree	8	8	8	F
L. nitidum	Shiny Tea-tree	0	1	0	?
Thryptomene calycina	Grampians Thryptomene	1	4	3	R

Table 1. Continued.

Families and Species	Common Names	Healthy Zone	Transitional Zone	Diseased Zone	Species Status
Proteaceae					
Banksia marginata	Silver Banksia	1	0	1	?
Grevillea alpina	Mountain Grevillea	1	0	0	?
G. aquifolium	Variable Prickly Grevillea	8	8	8	F
Hakea decurrens	Bushy Needlewood	8	8	7	F
H. rostrata	Beaked Hakea	4	3	8	R
Isopogon ceratophyllus	Horny Cone-bush	6	1	0	S
Persoonia juniperina	Prickly Geebung	2	0	0	S
Rutaceae					
Correa reflexa	Common Correa	8	2	1	S
Sapindaceae					
Dodonaea cuneata	Wedge-leaf Hop-bush	0	0	1	?
Sterculiaceae					
Lasiopetalum macrophyllum	Shrubby Velvet-bush	0	0	3	R
Stylidiaceae					
Stylidium soboliferum	Grampians Trigger-plant	4	4	1	S?
Tremandraceae					
Tetratheca ciliata	Pink Bells	7	1	0	S
Monocotyledons					
Calectasiaceae					
Calectasea cyanea	Blue Tinsel-lily	1	0	0	?
Cyperaceae					
Caustis pentandra	Thick Twist-rush	4	4	3	F
Gahnia radula	Thatch Saw-sedge	3	5	1	?
Lepidosperma filiforme	Common Rapier-sedge	2	0	0	S
L. laterale	Variable Sword-sedge	0	0	3	R
Lepidosperma spp.	Sword-sedges	0	3	2	R?
Schoenus apogon	Common Bog-sedge	2	1	2	F?
Schoenus spp.	Bog-sedges	0	0	1	?
Juncaceae					
Juncus spp.	Rushes	0	1	0	?
Poaceae					
Amphipogon strictus	Grey-beard Grass	0	0	3	R
Poa spp.	Other Grasses	0	0	2	R
Stipa spp.	Spear Grasses	2	2	7	R
Restionaceae					
Hypolaena fastigiata	Tassel Rope-rush	7	8	8	F
Lepidobulus drapeticoleus	Scale-shedder	8	8	8	F
Xanthorrhoeaceae					
Lomandra filiformis	Wattle Mat-rush	2	0	0	S
L. glauca	Pale Mat-rush	3	1	3	F?
Lomandra spp.	Mat-rushes	2	0	0	S
*Xanthorrhoea australis**	Austral Grass-tree	8	8	7	S
Gymnospermae					
Cupressaceae					
Callitris rhomboidea	Oyster Bay Pine	5	5	2	S?

Moreover, the results of the seed/fungus test are consistent with the hypothesis that *P. cinnamomi* was the cause of the observed differences. It is, however, important to note that *P. cinnamomi* was not isolated in this study, and the results of the seed/fungus test may have been due to other fungal species. Nevertheless, the remainder of this discussion will proceed under the assumption that dieback noted at the study site was due to *P. cinnamomi.*

Vegetation Changes

Changes to vegetation structure at the community level involved the transition from *E. baxteri* forest with a low heathy understorey in the healthy zone, to a more open forest with many dead trees and an increased number of sedge and grass species in the diseased zone. This transition represents a substantial alteration in community structure, with a significant reduction in species richness. Other studies

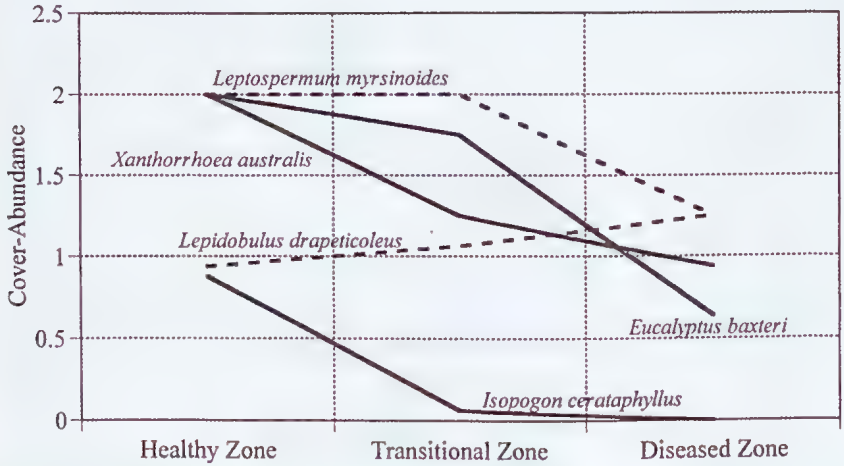

Fig. 4. An example of how the presence of *P. cinnamomi* affects the degree of cover of susceptible species (solid line) and fluctuating species (dashed line) within healthy, transitional and diseased zones. Susceptible and fluctuating species were defined on the basis of their frequency within each zone.

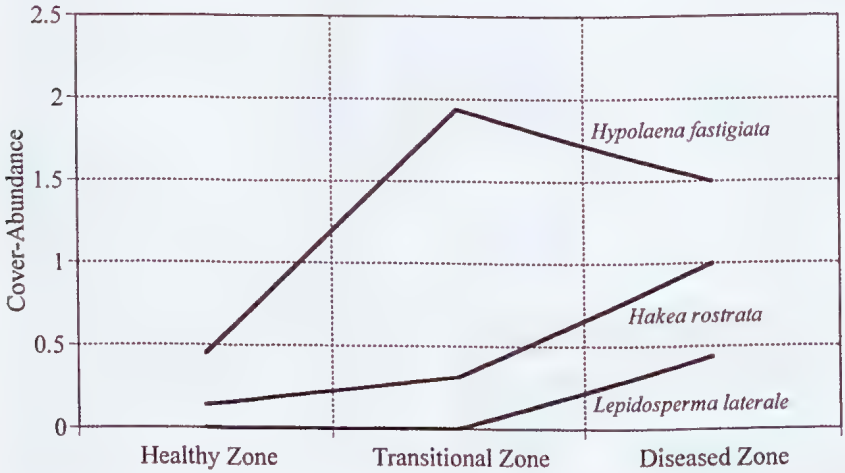

Fig. 5. An example of how the presence of *P. cinnamomi* affects the degree of cover of resistant plant species within healthy, transitional and diseased zones. Susceptible and fluctuating species were defined on the basis of their frequency within each zone.

(e.g. Duncan and Keane 1996) have also found changes to community structure resulting from *P. cinnamomi* infection to be substantial.

The response of vegetation to the presence of *P. cinnamomi* has been similarly described by Kennedy and Weste (1977, 1986) and Weste and Kennedy (1997) at other sites within the Grampians National Park. In the most recent study, these authors observed substantial changes in community structure without significant change in cover or (in contrast to the present study) species richness. Shearer (1994) also notes that *P. cinnamomi* can alter community structure within *Eucalyptus marginata* forest in Western Australia without a concurrent reduction in the number of species. Other studies from Western Australia, however, have suggest-

ed that species richness is reduced in areas infected with *P. cinnamomi*. In *Banksia* woodlands on the Swan Coastal Plain, Shearer and Dillon (1996) observed that, on average, diseased zones had seven fewer species than healthy zones. In this respect, the findings of the present study are similar. The results show that healthy areas accommodate more species than transitional or diseased areas.

Susceptible, Resistant and Fluctuating Species

All references to susceptible, resistant and fluctuating species in this study are based on the frequency of their occurrence in each zone (see Table 1). On the basis of this somewhat subjective analysis *Monotoca scoparia*, *E. baxteri*, *X. australis* and *I. ceratophyllus* provide examples of susceptible species. The susceptibility of all of these species has been previously recorded in the Grampians (Kennedy and Weste 1986; Weste and Kennedy 1997) and the latter two in the Brisbane Ranges National Park (Weste 1986). *X. australis* has also been identified as susceptible in Victoria's Kinglake National Park (Duncan and Keane 1996). Kennedy and Weste (1986) have identified nine other susceptible species that were present at the current study site; *Tetratheca ciliata, Hovea heterophylla, Astroloma conostephoides, Hibbertia fasciculata, Hibbertia stricta, Persoonia juniperina, Correa reflexa, Leucopogon ericoides* and *Leucopogon virgatus*. All of these species were identified as susceptible in the present study, with the exception of *H. stricta*, which showed a resistant trend.

Hypolaena fastigiata, L. laterale and *Leptospermum juniperinum* and *H. rostrata* exemplified resistant species. In the Grampians, Kennedy and Weste (1986) also identified *H. fastigiata* and *L. juniperinum* as resistant, while the abundance of *L. laterale* has been observed to increase within diseased zones at Kinglake National Park (Duncan and Keane 1996). *Gahnia radula*, a species also identified as resistant in this area (Duncan and Keane 1996), as well as in the Brisbane Ranges (Weste 1986), was not shown to be clearly resistant in this study. Although its abundance was higher in the transitional zone than in the healthy zone, its abundance fell to the lowest level in the diseased zone.

Fluctuating species identified in this study included *L. myrsinoides, L. drapeticoleus* and *Grevillea aquifolium*. In Victoria, *L. myrsinoides* has been widely identified as a fluctuating species (Kennedy and Weste 1986; Weste 1986; Weste and Kennedy 1997). However, in the Grampians, Kennedy and Weste (1986) observed *L. drapeticoleus* to be marginally invasive. *Casuarina muellerana* has also been identified as fluctuating in the Grampians National Park (Kennedy and Weste 1986). In this study, the density of *C. muellerana* was so low that its response to *P. cinnamomi* could not be identified.

Regeneration of Susceptible Species

The regeneration of seedlings of susceptible overstorey species (especially *E. baxteri*) was observed in transitional and diseased zones. Regeneration of susceptible overstorey species at old diseased sites has also been observed in other parts of the Grampians (Weste and Kennedy 1997). Although susceptible understorey species were not noted to regenerate in this study, the regeneration of many susceptible understorey species has also been observed over the longer term. Nearly a decade after the establishment of their Grampians study, Kennedy and Weste (1986) observed that susceptible species had not regenerated at infected sites. Twenty years after establishment, however, 24 susceptible understorey species from 11 different families were found to be regenerating in old infested plots. These results have been corroborated in other parts of Victoria (Weste 1986; Duncan and Keane 1996; Weste *et al.* 1999) and Western Australia (Wills 1993; Shearer and Dillon 1996).

It is likely that regeneration of susceptible species in old infected areas may be a result of pathogenic decline (Wills 1993; Duncan and Keane 1996). Pathogenic decline may occur for a number of reasons, including changes in the distribution of *P. cinnamomi* and a reduction in the amount of susceptible root tissue at infected sites. Regeneration of susceptible species may also occur if the potential of the pathogen to cause disease is reduced, due, for example, from increased resistance in some susceptible species. Although specific factors

causing pathogenic decline may be difficult to isolate, available evidence suggests that the impact of *P. cinnamomi* is reduced over time (Peters and Weste 1997).

Management of *Phytophthora cinnamomi* – a review

The management of *P. cinnamomi* throughout Australia poses significant problems, as there is no comprehensive solution to this disease (Dell and Malajczuk 1989; Bridgewater and Edgar 1994). At present, the major management strategies involve the isolation of diseased areas and the sterilisation of infrastructure moving in and out of diseased sites. These measures, however, are not expected to prevent the spread of the pathogen in the long term (Dell and Malajczuk 1989; Hill *et al.* 1995).

Investigations into alternative management practices are continuing. The use of potassium phosphonate to control *P. cinnamomi* has been investigated in a number of recent publications. Short term greenhouse trials have shown that potassium phosphonate can reduce the severity and incidence of disease in *Pinus radiata* (Ali *et al.* 1999) and a number of susceptible native species (Peters and Weste 1997; Ali and Guest 1998). A field study at Anglesea, Victoria, indicates that foliar phosphonate spray can help to control *P. cinnamomi* in forest and heathland communities, although some species exhibited phytotoxic effects at high concentrations (Aberton *et al.* 1999). In general, chemical treatment of infected regions may be an effective small scale management option if infected sites are identified early (Hill *et al.* 1995).

An alternative to chemical treatment is the use of biological controls. Biological control of *P. cinnamomi* involves the introduction of antagonistic soil micro-organisms into infected regions. Suggested bio-control mechanisms include the use of bioenhanced mulches (Costa *et al.* 1996) and the introduction of cellulase producing organisms into infected regions (El-Tarabili *et al.* 1996). These strategies, however, are primarily directed at controlling *Phytophthora* species in fruit plantations, and are not appropriate for use in the Grampians as the structure and organic content of the soil is not conducive to the survival of populations of micro-organisms (Kennedy and Weste 1986).

In the Grampians, Kennedy and Weste (1986) suggest that fire may be an appropriate management strategy. Severe fire kills *P. cinnamomi* in the top 20cm of soil (Weste 1974), and promotes regeneration in the fire adapted vegetation of the region. In addition, Kennedy and Weste (1977) propose that public education could aid the management of *P. cinnamomi*. Peters and Weste (1997) agree that education should be an important element of an effective management strategy. Informing people about *P. cinnamomi*, and the risk of spreading infection via vehicles and equipment may reduce its rate of spread in the Grampians National Park.

Areas infected with *P. cinnamomi* are not uniformly distributed – they form a non-uniform mosaic of infected patches across the landscape (Weste and Kennedy 1997). Consequently, developing a detailed inventory of diseased regions (Shearer 1994) and the identification of healthy but susceptible micro regions (Kennedy and Weste 1986) may help to manage infected areas. Barker *et al.* (1996) have developed an objective methodology for the selection of sites with a high management priority, and such objective delineation of more and less important areas seems like a logical first step in the development of a management plan.

Better management of *P. cinnamomi* in Australia requires the development of a national management plan. To this end, communication between management bodies in different parts of the country needs to be enhanced (Bridgewater and Edgar 1994). However, the impact of *P. cinnamomi* in a particular region depends on potentially unique interactions between the pathogen and the surrounding ecosystem (Bridgewater and Edgar 1994; Shearer 1994; Castello *et al.* 1995; Shearer and Dillon 1996). The earlier discussion, for example, shows that the same species may respond differently to *P. cinnamomi* at different points in space and time. As a consequence, management strategies, although holistic in nature, must be flexible enough to deal with problems specific to a particular region. This may require the use of different management strategies for different regions, or the integrated use of a number of management techniques to control *P. cinnamomi* in a particular area.

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Field Identification, Ecology and Conservation Status of the Red-chested Button-quail *Turnix pyrrhothorax* in Northern Victoria

Lawrie E. Conole[1] and Ralph Mac Nally[1,2]

The Red-chested Button-quail *Turnix pyrrhothorax* is classified as Vulnerable in Victoria (DNRE 2000). It is generally regarded as widespread, although uncommon (Pizzey and Knight 1997), in New South Wales, Queensland (CYPLUS 1996) and the Northern Territory (PWCNT 1999). In north-west Western Australia, O'Connor (1997a, b) reported three records from an environmental survey at the Argyle Diamond Mine (16°41'12"S 128°25'50"E) and another near Broome (17°57'47"S 122°14'06"E), which added to just six previous Kimberley records. Red-chested Button-quail are also rare in South Australia (Stanger *et al.* 1998; TSN 1998). Marchant and Higgins (1993) describe it as generally uncommon across Australia, but apparently secure. Bennett *et al.* (1998) thought it rare on the Victorian Northern Plains. Its status across Victoria is unclear – thought to be present most years in some regions, but only an occasional visitor to other regions depending on seasonal conditions (Emison *et al.* 1987).

The observations reported here come from a more extensive study of the vertebrate fauna of Gunbower Island, Barmah State Forest and the Lower Ovens Regional Park, which focused on the role of coarse woody debris (fallen timber) in influencing biodiversity on the southern floodplains of the Murray-Darling basin (Mac Nally *et al.* 2000).

Habitat use

Although generally considered a grassland species, we recorded Red-chested Button-quail in River Red Gum *Eucalyptus camaldulensis* and Black Box *E. largiflorens* woodland along the Murray River at Lindsay Island (34°08'S 141°07'E) and Gunbower Island (35°45'S 144°18'E) (L.E. Conole, *unpubl. data*). Other observers have found the species in box-ironbark forests at Dunolly in central Victoria (37°00'S 143°44'E) (G. Horrocks, *pers. comm.*) and Chiltern in north-eastern Victoria (36°07'S 146°37'E) (R. Clarke, *pers. comm.*). In New South Wales, Red-chested Button-quail have been found within box-ironbark remnants in farmland in the Capertee Valley (33°07'S 150°10'E) (D. Geering, *in litt.*). The species can be locally abundant in these areas, as appears to be the case on Gunbower Island where it outnumbered Painted Button-quail by about 5:1 at one site (L.E. Conole, *unpubl. data*).

The common factors in these woodlands and forests seem to be areas of bare ground and abundant leaf litter, little or no understorey and patches of tussock grass or sedges. In River Red Gum habitats, there are often drifts of flood debris. This combination of conditions most commonly occurs along drainage lines. The birds normally forage in open areas of deep leaf litter, and retreat to the cover of tussocks or woody debris if threatened. This is contrary to the description in Marchant and Higgins (1993), which suggested that Red-chested Button-quail prefer thick standing ground cover of grasses or weeds.

We believe its occurrence in open woodlands in Victoria may be significantly underestimated, which in turn leads to its overall status in Victoria most probably being in error. The species appears to be a regular visitor to woodlands in northern Victoria, if not a resident. Emison *et al.* (1987) regarded River Red Gum habitats along the Murray River to be the habitat in which Painted Button-quail reach their greatest densities. Even so, it is also the case that Red-chested Button-quail outnumber Painted Button-quail in areas of Gunbower Island and Lindsay Island. We recommend that observers should be wary

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of presuming button-quail in woodlands of northern Victoria to be Painted Button-quail. All 'quail' should be scrutinized carefully before making an identification.

Field identification

Identification of Red-chested Button-quail in the field is probably easier in woodland than in some of the grassland habitats they frequent. We have found Red-chested Button-quail more reluctant to fly than Painted Button-quail. In dense ground cover, birds are probably missed as they run out of the path of the observer rather than flush. In woodland, Red-chested Button-quail typically flush quite late – 2-10 m from the observer. On the other hand, Painted Button-quail typically flush earlier – 20-50 m from the observer. Red-chested Button-quail also often allow a longer period of observation in flight than Painted Button-quail. They can generally be relocated after the first flushing, but rarely after a second. When first flushed, Red-chested Button-quail typically fly a short distance, land and then stand motionless to inspect the 'intruder'. After being flushed a second or third time, they usually run out of view very quickly.

The key characters to look for to identify Red-chested Button-quail are:

- clearly smaller in size than Painted Button-quail;
- when viewed from directly behind Red-chested Button-quail look uniformly pale grey across the upperwings and back compared with Painted Button-quail, which are two-toned, warmer brown-grey on the back with greyish upperwings;
- Little Button-quail *T. velox* are clearly pinkish-cinnamon on the upperparts;
- when viewed from side-on, the rufous wash on the underparts of Red-chested Button-quail is obvious, and the thick bill may be seen at close range.

If viewed on the ground, either before flight or when located after landing, the characteristic plumage and bill-size differences can be sought.

Once Red-chested Button-quail had been identified as the most abundant species of *Turnix* at '86 Break' (a forestry track) on Gunbower Island, a number of observers visited the area and found they were able to distinguish between the two species in flight, after a little practice (C. Coleborn and C. Lester, *pers. comm.*).

Foraging

Although Marchant and Higgins (1993) mentioned that Red-chested Button-quail '... glean and scratch in litter ...' and use small circular scrapes for roosting, it is not clear from that description whether they make platelets in the course of foraging in the manner of other species of *Turnix*. Platelet making for foraging has been observed at Gunbower Island (L.E. Conole *pers. obs.*; C. Tzaros, *pers. comm.*) and is typical for the genus. The birds rotate on the spot, scratching out a small circular depression in leaf litter, pecking occasionally at the ground, and can sometimes be detected in dry periods by the small puffs of dust they cause while making the platelets. Foraging occurs throughout the day, although the species has been said to be nocturnal and crepuscular (Marchant and Higgins 1993). In areas where Red-chested Button-quail were found to be abundant, the density of platelets over large areas of ground was marked and relatively uniform (e.g. 10 platelets/m^2, 27 April 1999). At one logging coupe on '86 Break' on Gunbower Island, Red-chested Button-quail concentrated foraging – for a short period – around the gouges and depressions made in the ground where sawlogs had been dragged through the woodland.

Status and threats

The Red-chested Button-quail is categorized as Vulnerable in Victoria (DNRE 2000), but is thought to be uncommon and secure throughout the rest of its Australian range (Marchant and Higgins 1993). Few records were made of Red-chested Button-quail in Victoria during the first Atlas of Australian Birds (Blakers *et al.* 1984), and all of these were from grassland or crops. Although it may be irruptive south of the Great Dividing Range and into drier areas of the Wimmera and Mallee of western Victoria, we believe Red-chested Button-quail may be a regular visitor or resident along the Murray River floodplain in northern Victoria. We have found it to be locally more abundant than Painted Button-quail in areas of River Red Gum and Black Box woodland on Gunbower

Island and on Lindsay Island. Although Red-chested Button-quail may be relatively rare in Victoria, it seems to occur more regularly and widely, and utilizes more habitats, than previously thought.

Given that areas of ground cover such as tussock grass or sedges and woody debris seem important to Red-chested Button-quail, we recommend that these habitat elements be managed in riverine forests to ensure appropriate conditions for this species. Grazing by livestock, and removal of woody debris for firewood, are threatening processes for the Red-chested Button-quail in these floodplain woodlands.

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Observations of Skink Mating Behaviour

On a warm, sunny, summer afternoon (10 October 2000) I noticed what at first sight appeared to be a heap of dead garden skinks (*Lampropholis guichenoti*). Closer examination revealed that all were very much alive and that the heap had a definite structure. There were five skinks involved and all were on their backs. The central skink was held to the ground by the jaws of two others attached to each flank. The purpose of this behaviour soon became apparent when one of the attached skinks raised the rear half of its body (with its rather messy intromittent organ at the ready) and curved it over the female. After a union of several seconds the group broke up and the female escaped only to be pinned down again after travelling about 70 cm. As there were a number of excited skinks about I am not sure whether the same group reconvened. I suspect that the matings had been going on for some time and that many males were involved. The sex of the assistants was not obvious to me. The behaviour seemed risky – the cluster of lightly hued bellies was very conspicuous. Furthermore, their natural wariness was lacking. They would have been easy pickings for kookaburras etc. However, the strategy is obviously successful judging by the abundance of these skinks. They are communal nesters and in my limited experience the hatchlings are all ready to emerge at the same time.

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Observations of Black Snake Feeding

Since taking up part-time residency on a Genoa River property in Far East Gippsland I have had many opportunities to view animals I would not otherwise have encountered. Red-bellied Black Snakes (*Pseudechis porphyriacus*) appear to be common and are usually observed curled up in a sunny spot or fleeing. Sometimes a moving snake will 'freeze' when confronted by a walker or vehicle. A 'frozen' black snake can be encouraged to move out of harm's way by very gentle contact – a longish stick is recommended as they can 'thaw' quickly. Very occasionally I have seen a black snake sampling scents with its tongue as it moves over rocks and litter, but until recently I had never seen one feeding.

At midday on 22 December 1999 I saw a loop of active black snake protruding from a shallow pool isolated from the river by lack of rain. The approximately 130 cm long snake was working its head under a rock in about 10 cm of water. Suddenly it emerged with a galaxid about 7-8 cm long. The front two-thirds of the fish was visible. Swallowing was assisted by pushing the galaxid against rocks and against its own flank. All this occurred underwater.

The snake resumed hunting in a systematic pattern by vigorously working its head into every available crevice close to where it caught the fish. It would surface periodically for air – its breaths were audible – and then return to the crevices. It varied its approach to any one ledge, sometimes approaching from the left and sometimes from the right. Occasionally there were forward thrusting movements of the body but as the head was out of sight I could not see what was happening. Periodically it would raise its head from the water and check the immediate pool surrounds before resubmerging. Several times it swam to the centre of the pool (depth about 30 cm) where it swept through the sediment before quickly returning to the crevices. Eventually it swam the 3 to 4 metres to the other end of the pool forcing its way into more ledges and through a patch of aquatic vegetation. This resulted in a galaxid leaping from the water onto a rock shelf. While the snake was not looking, I moved from my vantage point and returned the stranded fish to the pool. Without going back to my former position, I continued to watch. I could see that this reptile had disturbed tadpoles, shrimps and a larger decapod. Then the snake abandoned its ledge search and swam into the shallows and raised its head. I found myself 60 to 70 cm from a hyped-up snake with its tongue still flickering. I remembered reading that 'you would be very unlucky to be killed by a black snake'. As I resolved to hold my ground another part of me calculated I was within striking distance and also that any help was hours away. Suddenly my legs stepped backwards and equally suddenly my snake vanished into its pool.

It had been a fascinating half-hour. I was left with the distinct impression that this animal had been working to a plan – a strategy involving the stirring-up the centre of the pool so that potential prey fled into ledges or even out of the pool where it would be easier to catch. The snake also seemed to position its body to act as a sort of barrier to stop potential food escaping to deeper water. If this was the strategy, was it learned by trial and error or was it insight or was it an innate behaviour?

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Birds of French Island Wetlands

by Des Quinn and Geoff Lacey

Publisher: *Spectrum Publications, PO Box 75, Richmond Victoria 3121.*
ISBN 0 86786 271 8. 153 pp., paperback RRP $20.

French Island in Victoria's Western Port Bay is, in many ways, a jewel in the State's flora and fauna heritage, particularly from the avifaunal viewpoint. The island occurs in one of the State's largest Ramsar (internationally recognised wader and waterbird habitat) sites. As with a number of other important sites across the State the island has a 'Friends group' that carries out much important work. Authors Des Quinn and Geoff Lacey, founding members of Friends of French Island, communicate their enthusiasm, interest and commitment to preserving and recording the water and wader birds of the island with this fascinating and well produced book that deserves wide appreciation by all Victorians, not just those interested in birdlife.

The book is divided into five sections: an 'introductory' section on the island and its wetlands, then sections on the coastal wetlands, inland wetlands, wetland birds and their ecosystems and finally wetland management guidelines. Much in evidence is the authors' use of their own data and hand-drawn illustrations, with assistance from many others who are carefully acknowledged.

The book opens with some notes about the authors then gives some brief comments on the island's Aboriginal and European history and other Western Port bird studies. The authors then outline the books' purpose in five points: the publishing of their records and an interpretation of this data; exploration of species and their habitats and hence the importance of the area; guidelines for management of the wetland sites; to show how individuals and groups can achieve conservation goals; and finally to highlight methodology used on the study of the island's wetlands as a means to compare these sites with wetlands elsewhere in Victoria and Australia. Some brief information is given on the island's geology and wetland ecology before the main chapters dealing with the wetland sites.

The chapters on coastal and inland wetlands are clearly laid out so the naturalist or new visitor can gain an insight into each site's water or wader bird community. Common and scientific names are used and the text is supported by hand-drawn maps plus a few illustrations. The importance of each site is stated and notes from the authors' own notebooks are interspersed with the text. This adds a personal dimension that communicates their enthusiasm while giving the reader an immediate impression of a site or observation. Where a site is particularly significant within Victoria or Australia, this is noted and other information sources are clearly referenced.

The last two parts of the book put the bird and wetland data into a State or ecosystem context. Some opinions are given on trends in numbers of species at certain sites, and the state of Western Port's seagrass community is briefly discussed. There are a number of useful tables including a complete (including terrestrial) bird list and records for most wetland sites mentioned in the text. Management guidelines for the wetlands are also discussed based on the Department of Natural Resources and Environment Guidelines of 1996 (NRE 1996).

I had a minor criticism about the images used. Most of the bird photographs in the text are from the Ian McCann collection and unfortunately a number are repeated in different parts of the book. Likewise the line drawings of birds. However, it is the authors' own images of the wetland habitats that are the most interesting, as they show what some sites actually appear like on the ground.

The authors have produced a book that not only details the numerous and varied wetland sites on and around the island but also gives an account of the interaction between the birdlife, their habitats and the chemo-

physical environment. Although it is not especially a book for the casual tourist, any visitor would find in the publication valuable resource material prior to visiting or if they wished to research the island's water and wader bird fauna. It is a delight to see the use of original, long-term data presented in a complete and informative format that will allow further analysis by the interested observer. The authors' 35 years of observations are clearly evident in this fact-filled publication. For those interested in French Island bird fauna this is an important text to add to your library. It is also the first book to attempt to record and publish details of a major vertebrate group for the casual visitor and ornithologist alike. While not a field guide or a handbook for the pack, I thoroughly recommend the book to all interested in Victorian fauna.

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Common Australian Fungi: a Bushwalker's Guide

by Tony Young

Publisher: *University of New South Wales Press Limited, Sydney, Australia, 2000. Revised Edition. 154 pp, 16 watercolour plates, 16 photographic plates, softback. RRP $22.95*

I suspect this little volume now holds the record for the number of different editions of essentially the same work, this being the fourth, although two are minor revisions of a previous publication – well on the way to becoming a bibliographic nightmare!

The latter pair have photographs to supplement the watercolour illustrations, minor updates in terminology, an additional introduction and a revised introductory paragraph for the work proper. The watercolours in the latter pair have been separated from their original taxonomic sequence and regrouped alphabetically, and are poorer reproductions than in the first pair. The shape and covering have also changed from hard covered 'paperback' size to a longer narrow paperbacked pocket size. The only difference I could detect between this '2000 bushwalkers guide revised edition' and the '1994 naturalist's guide edition' was a change in key entry 54 (p. 28) and the insertion of *Pycnoporus* here and *Pycnoporus coccineus* at p. 39 and in the index. At the index entry, you will also see a reference to plate 23, where you will look for it in vain, until you realise that it has the caption *Trametes cinnabarina*. (This name change is unexplained in the text, and similar unexplained changes also occur within a few genera.) Unfortunately, a number of such 'design flaws' mars this and the earlier editions, (all by the same publisher), the two most glaring of which are the use of 'old' names in both the key and often illustrations, as opposed to 'new' names in the text, and the failure to indicate plate numbers in the text, which means you are forever thumbing backwards and forwards or using the index.

So, into the work! The 'many hundreds of species of microfungi' alluded to in the introduction is one of the greatest understatements I've ever seen. Perhaps hundreds of thousands. Maybe millions. A single decaying leaf would probably supply the 'many hundreds'. We then run briefly and reasonably interestingly through the main fungal groups, which are illustrated with good, though small, but always unscaled line drawings. I have never, however, seen an entire *Cordyceps* ascospore liberated as illustrated in Figure 9r (p. 8) – they usually break into about 100 tiny barrel shaped part spores. The remaining sections of Fungi in the Bushland are general-

ly adequate, although the section on Fairy rings (pp. 10-11) would have benefited from the inclusion of reference to the research indicating the fungal structures underlying fairy rings may be the largest living things on earth! Also adequate (for a bushwalkers guide) are the following sections on Fungi and People and Poisonous and Edible Fungi, though again, there is no reference to the now common use of fungi (usually yeasts) in the genetic engineering of various products.

The Study of Fungi is fine for those already 'in the know', but would benefit from simple illustrations on 'how to ...' – how to make a spore print, section, slide and the like, perhaps a sample record sheet for beginners. The Key itself appears, from my relatively limited knowledge, to be satisfactory, except, as indicated above, for the use of discontinued names – eg. Pleurotus. Cordyceps keys out, assuming you know, or can observe the spore mass is not 'slimy and foul or foetid'! The key does not, however, indicate on which page the species descriptions begin – you have to look this up in the index.

The species descriptions are alphabetic within orders organised roughly taxonomically – a fairly common pattern. The ordering of the watercolours is now purely alphabetic, and the photographic plates appear to have been inserted at random. There is no indication of scale with any of the illustrations – you have to work this out from the species description. The descriptions themselves appear adequate, although again the accompanying (often useful) diagrams where present are both unlabelled and unscaled. Newer terminology has been included as subtext following or under the 'old' name, which is the one used to position the species in the text. Important information re edibility is clearly displayed – you can't say you weren't warned!

The sixteen photographic plates are of good to excellent quality. All would aid in the identification of the species depicted. The sixteen watercolour plates, while intrinsically beautiful, are of variable use with respect to identification and all illustrations are small. I do not, for instance, think I would identify *Lactarius deliciosus* from its illustration (Pl. 18), though I might *Cordyceps gunnii* (Pl. 6).

The work concludes with a useful glossary and further reading, although you would need inter library loan to get hold of some of these! Interestingly, although this contains the more recent releases, it is a considerably cut down version of the bibliography presented in the first 'pair'.

Despite the above criticisms, this is a useful guide, and it is a pity it does not carry a reference to the Fungimap scheme (many target species are included). There are an awful lot of fungi out there, and precious little information on any of them. This work, while suffering from a number of design faults, would enable the lay person, with a bit of effort, to enter in a practical way into the fascinating world of fungi. How many you could identify on a bushwalk – well, that's another question!

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Wildflowers of the Brisbane Ranges

by Clive and Merle Trigg

Publisher: *CSIRO Publishing, Collingwood, Victoria, 2000.*
128 pp, colour photographs. RRP $19.95.

Photographic records of the wildflowers of a region, locality, state or national park collected into books are becoming popular, perhaps with the availability of funds for such projects from government departments. This book is no exception and the authors, based on their experience of 10 years of observation, have compiled a collection of over 400 of the 430 species of the Brisbane Ranges National Park.

Brisbane Ranges National Park is situated 80 km west of Melbourne and 30 km north west of Geelong and boasts a wide range of soils, aspects and terrain that support grassy plants, dry open forests, woodlands, moist shaded sites, rocky sites and dry sandy areas. This is reflected in the rich diversity of the flora.

There is a short introdyctory section on the history and the events that shaped the Brisbane Ranges beginning 450 million years ago, with comments on Aboriginal and European settlement, gold, Geelong's need for a water catchment, timber removal and the adoption of the Brisbane Ranges as a National Park.

The main part of the book is of course the photographs of the flowering plants of the Brisbane Ranges. The species are arranged alphabetically under family and then species. The monocots appear to come first, represented by the Liliaceae and Orchidaceae and a few other family groups. A clump of *Xanthorrhoea australis* (family Xanthorrhoeaceae) with spikes in full-flower is immediately followed by *Carpobrotus modestus* (family Aizoaceae) with no explanation for the change back to the start of the alphabet. Plants are in two groups but there is nothing to explain this.

Some of the larger or more important family groups begin with a descriptive paragraph detailing the characteristics of the family in growth form, leaves, flowers and fruits. Details presented with each photograph are scientific name, common name, family, some limited detail on growth form (herb, shrub, erect annual, tufted herb), height of plant, flower arrangement and width (e.g. capitula to 30 mm, buttons to 15 mm, flowers in clusters, flowers in brown plumes). A short phrase describes where these plants may be found (dry areas, damp flats, widespread in forests, poor stony ground) and when they flower.

There are two very useful aids to identification of plant species in this book. One is the 'colour identification guide', which groups colour and the types of flower arrangements likely to be found in that colour. For instance, under 'pink or red' flowers may be arranged as daisies, peas, spikes and umbels (to name just a few) whilst 'green or brown' can be buttons, clusters, cylindrical or tubular. Page numbers refer to the main photographic section. Secondly, letters after the location of plants refer to the Soils of the Brisbane Ranges map in the back end-paper of the book. Each soil region is shaded with a unique colour and numbered from A-L. Knowing where you are when you try to identify species may aid in differentiating between similar species and genera (provided you are not already lost!).

The photographs are excellent, clear and detailed and provide a close-up view of each subject. Some species are represented twice with another photo to give more detail, e.g. the flower of *Caleana major* followed by a photo of its leaves, or *Eucalyptus camaldulensis*, a photo of the tree and one of the leaves and buds. Ideally, there would have been more photos of growth form as well as flower close-up, but perhaps there was not room or the budget would not allow extra photos. Ideally, too, there would have been more detail in the text to draw attention to the characteristics that differentiate similar species from each other, such as flower and leaf form.

There is a map of Brisbane Ranges National Park, which includes local and park roads, walking tracks, barbecue and camping areas and an index, glossary and a list of references.

On the whole, this is an excellent publication and I look forward to visiting Brisbane Ranges National Park, book in hand, to locate and identify many of these plants for myself.

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For assistance with the preparation of this issue, thanks to Maria Belvedere and Karen Dobson (label printing), Dorothy Mahler (administrative assistance) and Michael McBain (web page).

Field Guide to the Orchids of New South Wales and Victoria Second Edition

by Tony Bishop

Publisher: *University of New South Wales Press, Sydney, 2000*
344 pp., incl. 72 colour plates. RRP $37.95

'Field Guide to the Orchids of New South Wales and Victoria 1996', will be well known to orchid enthusiasts. It is quite simply the best available, complete field guide to the orchid species found in South Eastern Australia. The second edition has been updated by David Banks, John Keller and John Riley. Two main revisions have occurred. In the first edition, Tony Bishop covered a number of species that had not been formally described. Since his death, many of these have been described and named. For example, the lovely spider orchid I first admired last October is described, in the first edition on p.149 as *Caladenia sp. Aff. reticulata (Dalyenong)*. It is now listed as a full species, *Caladenia cruciformis*, 'distinguished by its rigid cross-shaped crimson flowers with clubbed sepals'. Secondly, the genus *Dendrobium* has been split into two genera, *Dendrobium* and *Dockrilla*. The descriptions and key reflect these changes. However, for the general user, the revisions could be considered relatively minor. The book remains compact and easy to carry on field trips, although the paper used in the second edition is a poorer quality than that of the first.

For those who are unfamiliar with it, 'Field Guide to the Orchids of New South Wales and Victoria', is divided into three main sections. The first contains detailed information for each species of orchid, systematically covering distribution and habitat, identification, similar species and field notes. These descriptions are arranged by botanical affinities, not alphabetically. The second section contains over 500 high quality colour photographs of all taxa described. An index to the colour plates gives specimen location and photographic credits. Finally there is a comprehensive key to the orchid genera and species of New South Wales and Victoria. The book also contains a glossary and index.

The photographic work, mainly by Tony Bishop, is outstanding. The photographs are close ups, mostly taken by flash in situ, and especially selected to aid identification. The standard and consistency is awesome. I checked on the illustrations of two orchid genera difficult to identify because of their small size, Midge Orchids *Genoplesium*, and Onion Orchids *Microtis*, and they are wonderfully clear and sharp. Only one new photograph, a superb illustration of the Long-tailed Greenhood *Pterostylis woolsii*, with its 10-15cm long lateral sepals, is included in the second edition. A continuing frustration is that the illustrations are still not named in the new edition. They are linked back to the text only by a number, requiring a certain amount of flipping back and forth.

At a list price of $37.95 this volume is a 'must buy' for all orchid lovers, botanists, bushwalkers, and field naturalists. However, many who already own the book will probably not immediately update to a second edition of what is substantially the same work.

Joan Broadberry
2 Shaun Court,
Templestowe, Victoria 3106.

Native Orchids of Southern Australia: A Field Guide

by David and Barbara Jones

Publisher: *Bloomings Books. 37 Burwood Road, Hawthorn, Victoria 3122. 272 pp., 275 full colour photos. RRP $29.95*

The introduction to 'Native Orchids of Southern Australia' states, 'This book presents a sample of the native orchids which occur naturally south of latitude 27°S. This line passes close to Brisbane on the east coast of Australia, and Kalbarri on the west. Approximately one-third of the indigenous orchids found in this region are included.' Unusually, this means that orchids from Western Australia and South Eastern Australia are grouped together. The authors' aim, explained in the Preface, is to produce 'a simple field guide to introduce these special native plants to a wide audience'.

I will say at the outset, 'Native Orchids of Southern Australia' has some difficulty fulfilling its stated aim, because, although published as a field guide, it covers only one third of possible species. Size and cost are constraints, but anyone more than a casual user would find this book inadequate as a single field guide to the orchids of Western and South Eastern Australia. This is an obvious criticism that will limit its appeal, but what are the book's strengths?

David and Barbara's new publication is a handy size and weight for a field guide, and has a simple easy to use structure. A brief introduction covers the basics of orchid ecology. The major part of the book deals systematically with each chosen orchid species. A colour photograph, botanical and common names and a straightforward description are provided. Overall distribution, flowering period, habitat and field notes are covered, and in many cases, differences from similar species are outlined. The field guide finishes with a short glossary, references and a very clearly set out index. The general user would find its alphabetic arrangement of orchid genera very convenient.

As a keen native orchid enthusiast, two things drew me to buy this volume even before I was asked to review it. Firstly, its illustrations. Many are truly mouth-watering and a great aid to learning more about native orchids. The photographs I appreciated most are those showing groups of orchids in their natural bush habitat. Examples include the Leafy Greenhood *Pterostylis cucullata*, the Tall Leek Orchid *Prasophyllum elatum*, and the Red Beaks Orchid, *Pyrorchis nigricans*. I wish more publications would include such gems. I was also fascinated by the excellent photographs of the Western and Eastern Underground Orchids *Rhizanthella gardneri* and *R. slateri*.

In some cases an accessory photograph taking in leaves, stem, or from a different perspective is also included. The main photographs of the Channel Leaf Cymbidium *Cymbidium canaliculaltum*, and the Sweet Cymbidium *C. suave*, actually show the dense clumps of green pseudobulbs attached to trees. The flower racemes are only shown in the smaller, inset photograph. I have never seen these orchids and such a treatment really helps me to understand how they would appear in the bush.

Secondly, I was drawn to the book's wide coverage. I have not yet had much opportunity to seek out orchids interstate, and want to be exposed to orchid genera and species I cannot see in Victoria. Such a book allows less experienced orchid enthusiasts, such as myself, to learn without being overwhelmed, as might happen with a larger volume.

I believe then that 'Native Orchids of Southern Australia: A Field Guide' does, to a great extent, fulfil its purpose.

In comparison with native birds there is still very little literature covering Australia's magnificent native orchids. It is such a pleasure to welcome not just one, but two new publications. In their different approaches they will enable both the expert and the beginner to extend their knowledge of these unique plants.

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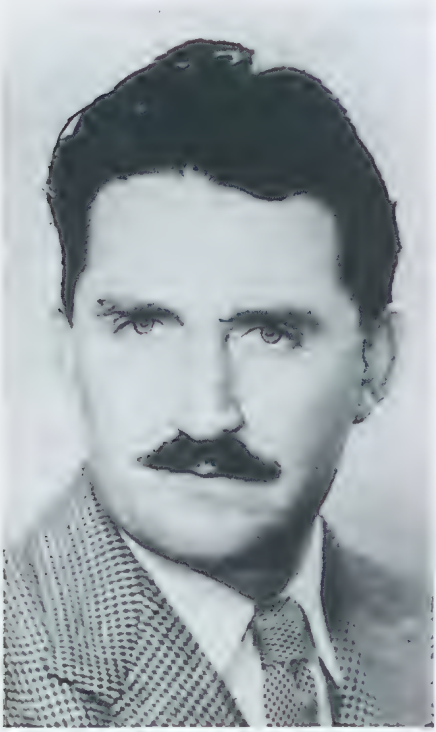
Templestowe, Victoria 3106.

George Anthony Thomas, B.Sc., Ph.D. (Melb.)

30 June 1921 – 13 November 2000

Dr George Anthony Thomas loved and had a great respect for the natural world. It is therefore not surprising that he joined the Field Naturalists Club of Victoria, at an early age (on 10 August 1942) and went on to become an honorary member. *The Victorian Naturalist* was an important part of his library and was read with great interest.

George was born in Northcote in 1921. He was the eldest of six children (sisters Shirley, Valda and Patricia, brothers Kenneth and Warren) born to his father, George, and his mother, Dorothy McMahon. The family lived in Clifton Hill. George's interest in nature, in particular geology, began with his childhood rambles, complete with dogs in tow, up and down the banks of the Merri Creek. He was quick to notice the massive layers of (Quaternary) basalt overlying the obviously different older (Silurian) rocks beneath.



The young geologist George Thomas in 1952, shortly after joining the Bureau of Mineral Resources.

He attended St. John's Primary School, Clifton Hill and St. Thomas's Christian Brothers Secondary School, Fitzroy before achieving a place at St. Kevin's College in Toorak to undertake his Leaving Certificate. However, the aftermath of the Great Depression was still widely felt throughout the community and George, well aware of the scarcity of the necessities of life and his parents' position, left school to work as a copyboy for *The Herald* newspaper. Nevertheless, George never gave up his love of reading, learning and science and he enrolled part time at the Austral College in Collins Street (Melbourne) in order to complete his Matriculation Certificate. He was later to take up a junior position at the National Museum of Victoria.

In 1940, George gained a place at the University of Melbourne where he commenced a science degree with major studies in Geology and Zoology. On the 16 June 1945, during the King's Birthday weekend, he married a fellow geology student, Nancy Mary Fenwick-Barbour, at St Patrick's Cathedral, East Melbourne.

This was the time of the Second World War and, as a student, George was a corporal in the Melbourne University Rifles. His father, a veteran of the First World War's Western Front, advised George that an officer's life was preferable. The National Museum of Victoria had a use for George until 1944 when he enlisted in the Royal Australian Air Force as Pilot Officer George Thomas. With his background in Geology, he was drawn into the new area of Operational Research on such tasks as air photo interpretation. He then took part in the Allied invasion of the island of Borneo.

After the War, new opportunities in Geology resulted in George joining the Commonwealth Bureau of Mineral Resources (BMR), Geology and Geophysics in 1948. George, Nancy and new daughter Marianne moved to Canberra

in 1949 and son Paul was born in 1951.

On joining the BMR, George commenced field work in the Carnarvon Basin, Western Australia under the leadership of Curt Teichert for 'a couple of weeks'. The 'couple of weeks' became 5 months! Communications were limited in such a remote region and so it was that George and half the Western Australian outback heard the news of Marianne's first tooth – courtesy of the Royal Flying Doctor's radio network.

George further developed his interests in fossils during the field seasons in the Carnarvon, Canning and Bonaparte Basins of the West. In particular, fossil brachiopods from the Devonian to Permian were to capture his imagination. He enrolled for a Ph.D. at the University of Melbourne and spent time at the University in the mid 1950s, graduating in 1961. He joined the staff of the Department of Geology at the University of Melbourne in 1960 and was a Senior Lecturer in that department until his retirement.

In 1960 George, Nancy and family returned from Canberra to live in North Melbourne and then Ivanhoe. The family continued to grow with the arrival of Peter and then Michael and Andrew.

George's geological work, covering such areas as field work and mapping, stratigraphy and palaeontology, is preserved in a range of monographs and articles. It is characterised by meticulous detail and significant discoveries. Amongst the latter were the discovery and proving on palaeontological grounds of the existence of an Early Carboniferous succession in the Canning Basin and the palaeontological proof of a Late Permian Tatarian (or Wuchiapingian in current terms) succession in both the Canning and Bonaparte Basins. These and other significant discoveries, which have had major impacts on Late Palaeozoic Gondwanan and global correlations, are to be found in the published literature. George himself, with characteristic modesty, never trumpeted his achievements.

Dr. George Thomas in 1999. Photos kindly supplied by Mrs. Nancy Thomas.

George, often with his family, travelled widely to Europe (including the then USSR), India, Asia and the Americas. These travels extended his range of geological friends but were also opportunities to extend his wide cultural and historical interests. George's broad interests, and knowledge, were vast as testified by a glance at the library in the family home at Ivanhoe. Lengthy discussions would range through philosophy, religion, and fine art, to subtleties of American Civil War History. However, above all, he was a family man and a true gentleman. His was a life to celebrate and he shall be greatly missed by Nancy, his family and all who knew him.

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Members receive *The Victorian Naturalist* and the monthly *Field Nat News* free. The Club organises several monthly meetings (free to all) and excursions (transport costs may be charged). Field work, including botany, mammal and invertebrate surveys, is being done at a number of locations in Victoria, and all members are encouraged to participate.

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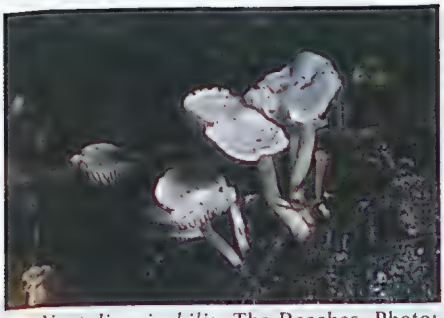


A. *Nyctalis mirabilis*, The Beeches. Photo: Bruce Fuhrer.

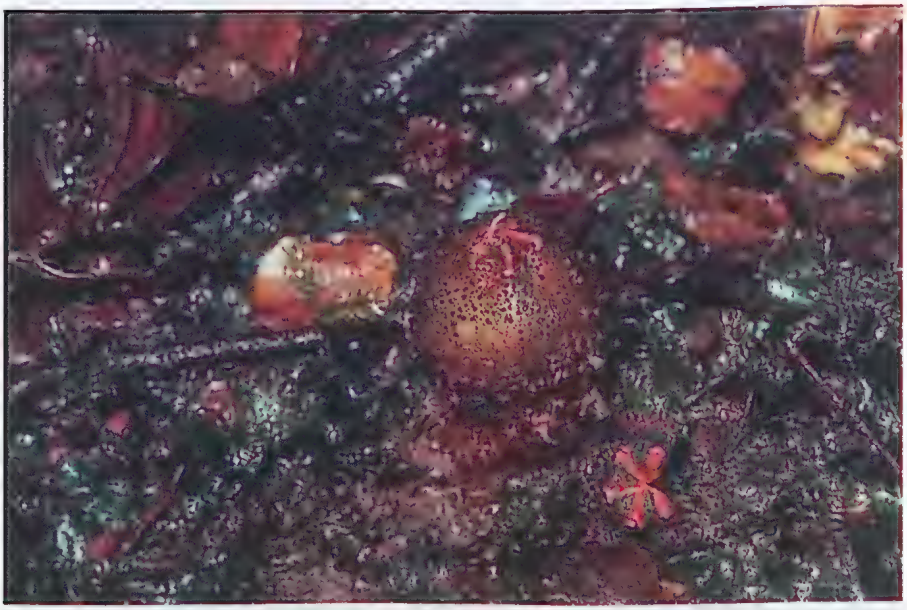
B. *Dictyopanus pusillus*, Mt. Kembla. Photo: Pat Jordan.

C. *Battarraea stevenii*, Victoria. Photo: Bruce Fuhrer.

D. *Hypocreopsis* sp., Nyora. Photo: Ilma Dunn.

PLATE 4

A. *Anthurus archeri*, Michelago Peak. Photo: Margery Smith.



B. *Calostoma rodwayi*, Otways. Photo: Ian McCann.

PLATE 5

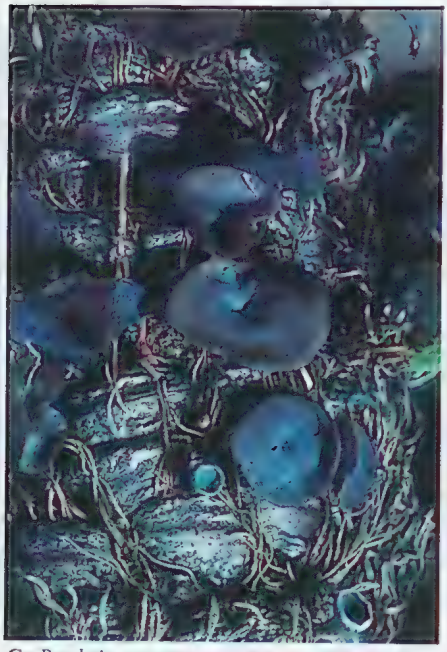
A. *Amanita phalloides*, Melbourne. Photo: Virgil Hubregtse.

B. *Rozites roseolilacina*, Grampians. Photo: Ian McCann.

PLATE 6

A. *Aleuria rhenana*, Dom Dom. Photo: Sheila Houghton.

B. *Dictyophora indusiata*, Innisfail. Photo: Bruce Fuhrer.



C. *Banksiamyces macrocarpus*, Kurth Kiln. Photo: Ilma Dunn.

D. *Craterellus cornucopioides*. Photo: Anneke Veenstra-Quah.

The Victorian Naturalist

Volume 118 (3) **June 2001**

F.N.C.V.

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A Large Weevil from the Simpson Desert

During a trek through the southern part of the Simpson Desert, west of Poeppel Corner, in July 1999, we crossed a number of salt lakes. These lakes form a prominent feature of the area and have a hard, dry crust (Fig. 1).

To my surprise members of our group found two large, dead weevils encrusted in the hard salt surface of two of these lakes and then, further east on another dry salt lake, a live specimen was found crawling sluggishly on the surface some distance from the edge of the lake.

The live Weevil was black with grey markings and heavily sculptured. One of the most interesting things was that the elytra (wing cases) were fused together, i.e. the weevil was flightless. Fusion of the elytra forms a protective shell for the abdomen and reduces moisture loss in the harsh conditions. The total length of this beetle was 35 mm, and was known to the group leaders as the 'Elephant Beetle' because of its prominently large rostrum (snout).

Since baggage was limited to one kitbag, I was unable to carry Zimmerman's 8-volume series on weevil identification and had to wait until my return to Melbourne. Fortunately, the specimens travelled well and one was photographed before the identification (Fig. 2). The identification was done using the dead beetles, the live one having been released in the desert after careful study. It was fortunate that Mr Bob Thompson, a weevil expert, was working at the Museum of Victoria and was kind enough to attempt the identification using E.C. Zimmerman's *Australian Weevils* (CSIRO Australia), and specimens from the MOV collections.

The weevils were identified as belonging to the sub-family Leptopiinae (Curculionidae) and most likely the species *Leptopius* (near) *gravis*. This sub-family is distinguished by a conspicuous scar on the outer surface of each mandible left by the detachment of a tooth used by the adult when escaping from the pupae (Lawrence and Britton 1994). Larvae of most species of *Leptopius* live in the soil and feed on the roots of wattles (Moore 1980) and, according to 'The Insects of Australia' (CSIRO 1970), on 'roots and foliage of *Acacia*'. The wattle species seen near these salt lakes were Dune Wattle *Acacia ligulata*, Victoria Wattle *A. victoriae*, Mulga *A. aneura* and Gidgee *A. cambagei*.

Fig. 1. Salt Lake in the Simpson Desert.

Fig. 2. The weevil *Leptopius* (nr.) *gravis* found on the lake surface.

The reason why these beetles were walking on the salt lakes remains to be explained.

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June

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Research Reports The Distribution and Abundance of Little Penguins at Sea in Western Port, Victoria, *by Peter Dann, Ros Jessop and Marg Healy* 76

New Tanjilian Fossil Localities at Dungaree Creek, Central Victoria, *by Clem Earp* 82

Contributions Addendum to 'Moss Collections from Lord Howe Island in the National Herbarium of Victoria (MEL)', *by Josephine Milne and Arthur W. Thies* 89

Effects of Grazing, Tourism and Climate Change on the Alpine Vegetation of Kosciuszko National Park, *by Pascal Scherrer and Catherine Marina Pickering* 93

Naturalist Notes A Large Weevil from the Simpson Desert, *by E.J. Grey* 74

A New Zealand Hepatic in Victoria, *by Alex McLean and David Meagher* 92

Ant Behaviour Part 2, *by E.J. Grey* 100

Book Reviews A Guide to Squid, Cuttlefish and Octopuses of Australasia, *by Mark Norman and Amanda Reid, reviewed by K.N. Bell* 101

Flora of Australia Volume 48: Ferns, Gymnosperms and Allied Groups, *reviewed by Maria Gibson* 102

Software Review Compendium of FUNGIMAP Target Species Version 1.0 [CD-ROM], *reviewed by Pat Grey* 104

Tribute Stefanie Rennick, *by Tom Sault* 106

Honours Lyle Courtney, OAM 107

Legislation *Flora and Fauna Guarantee Act* 1988 91

ISSN 0042-5184

Cover: Little Penguins *Eudyptula minor* arriving ashore at night after spending the day feeding at sea. See story on page 76. Photo by Scancolor Australia Pty. Ltd. and supplied by Peter Dann.

Our web page: http://calcite.apana.org.au/fncv/vicnat.html
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The Distribution and Abundance of Little Penguins at Sea in Western Port, Victoria

Peter Dann[1], Ros Jessop[1] and Marg Healy[1]

Abstract
The main aim of this study was to describe the patterns of distribution and abundance at sea of the Little Penguin *Eudyptula minor* in Western Port. Penguins were counted along an 81 km series of transects from a boat at approximately four-weekly intervals between April 1991 and August 1994. The mean number (± S.E.) of penguins seen per survey was 61.7 ± 10.4. Total numbers per count ranged from 0 to 214. Higher numbers of penguins were found in late autumn and winter and lower numbers in mid and late summer. In April 1994, when the number of penguins was greatest (214), we estimated that the total number of penguins in the bay was 383. Similarly, the mean for all counts (57.4) gave an estimate of 103 birds. This estimated maximum number was 1.5% of the estimated breeding population on the Summerland Peninsula.
Penguins were located mainly in the western and northern arms of the bay. Relatively few birds were seen in the shallower eastern arm and none over intertidal areas. The highest numbers of penguins per kilometre of transect were found along two transects in the centre of the bay at the confluence of the western, northern and eastern arms. Group sizes were small, 49% of 884 groups consisted of single birds and 94% of groups consisted of five birds or fewer.
Finally, the distribution and seasonal occurrence of Little Penguins in Western Port are discussed in relation to penguin movements and the biology and ecology of the fish species eaten by penguins.
(*The Victorian Naturalist* **118** (3), 2001, 76-81.)

Introduction

The distribution and abundance of birds at sea in Victorian waters are not well known. Learmonth (1966) gave some details of the occurrence of seabirds in western Victoria, as did Wheeler (1981) for Phillip Island, Simpson (1972) for Bass Strait and Norman (1992a, b) for waters south of Phillip Island. Some studies have considered seabirds in enclosed waters such as Port Phillip Bay (Pescott 1983; Norman 1992a, b) or surveyed the distribution and abundance of seabirds at breeding sites along the coast (Harris and Norman 1981).

Previous studies of birds in Western Port have been land-based and consequently concentrated on the waterbirds, waders and the few seabird groups such as cormorants, gulls and terns that congregate at roosting sites at high tide (Dann *et al.* 1994; Loyn *et al.* 1994). To examine the distribution of those seabirds which are less dependent on land, such as penguins, it is necessary to conduct surveys from boats at regular intervals and in a systematic fashion. The main aim of this study was to describe the patterns of distribution and abundance at sea of one locally breeding and abundant seabird, the Little Penguin *Eudyptula minor*, in Western Port between April 1991 and August 1994.

Methods

Western Port lies on the southern coast of Victoria, east of Melbourne, and covers 680 km^2 including 270 km^2 of tidal mudflats. It has a coastline of 263 km of which 107 km are lined by White Mangroves *Avicennia marina* (Shapiro 1975). One large island (Phillip Island) lies in the southern entrance and a larger island (French Island) occupies the centre of the bay (Fig. 1).

Thirty-six surveys were completed in the 40 months between April 1991 and August 1994. Boat engine failure and inclement weather caused four counts to be abandoned or postponed and prevented our attempts to maintain four-weekly intervals between counts. Little Penguins were counted along an 81 km series of transects (Fig. 1) from a boat travelling at 20-25 knots. The transects were perpendicular to the main channels to cover the entire range of sub-tidal water depths in each section of the bay. Intertidal areas were not traversed and subtidal areas less than two metres deep at high tide were also not counted with the exception of those areas in the eastern part of the Bay (Fig. 1).

[1] Phillip Island Nature Park, PO Box 97, Cowes, Phillip Island, Victoria 3922.

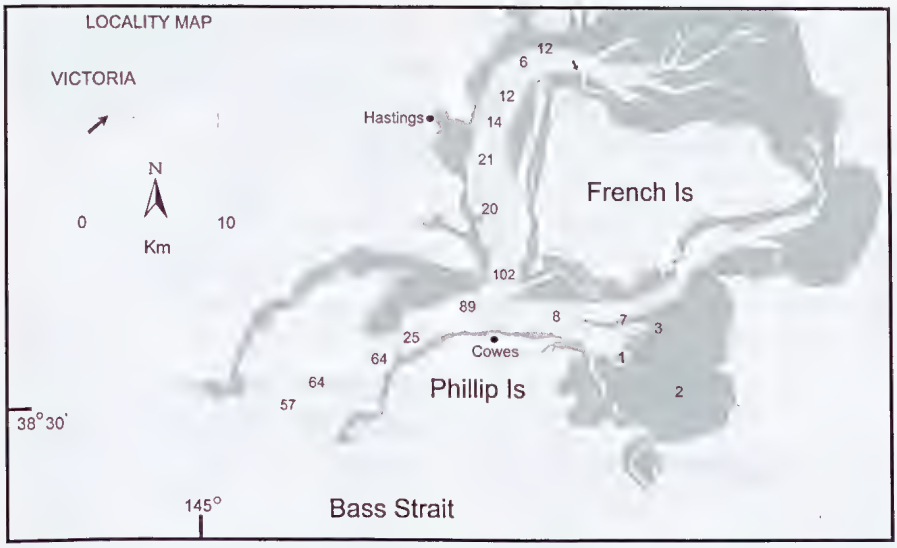

Fig. 1. The series of transects (black lines) used to count Little Penguins in Western Port and the total number of penguins per kilometre counted on each transect in Western Port. The shaded areas are those less than two metres deep at high tide and include all intertidal areas and some shallow subtidal areas. The small arrow north-west of French Island indicates the approximate position of Barriliar Island.

Usually two observers were stationed on either side of a seven-metre boat (eye height c. 3 m) and counted penguins in the right-angled sector from the bow to starboard or port. Observers recorded each penguin seen up to 500 m from the boat onto a tape cassette. When counting accuracy was impaired by either choppy sea conditions or larger numbers of penguins, the boat was stopped briefly while the counts were made. The observations made each time a penguin was seen included the time, transect, number of individuals and behaviour at the time. Difficulties of visibility caused by weather (Tasker *et al.* 1984) were reduced by only counting on days with wind speeds of less than 10 knots. The counts usually took five hours and were carried out around the middle of the day and, when possible, within a few hours of high tide. Identifications were made using 8 × 40 binoculars.

Total counts in the bay were compared with the monthly mean numbers of penguins coming ashore at Summerland Beach, Phillip Island and the total numbers of penguins with eggs or chicks in burrows. Penguins were counted for 50 minutes from the time of first arrival each night as they crossed Summerland Beach under lights at the Penguin Parade. Approximately 60% of birds coming ashore each night have done so by the end of this period (Montague 1982). The breeding data were collected during two-weekly visits (and combined in monthly samples) to c. 55 burrows at two sites on the northern side of Summerland Peninsula on Phillip Island (see Dann *et al.* 1995 for more details of data collection).

Results

A total of 2224 penguins was recorded on the 36 counts. The mean number (± S.E.) of penguins seen per survey was 61.7 ± 10.4. Total numbers per count ranged from 214 (April 1994) to 0 (June, November 1991 and February 1994) (Table 1). Greater numbers were found from mid-autumn to early winter in most years (April to June 1991, April to July 1992, April and May, 1993 and March to May 1994) and occasionally in late spring and early summer (October and December 1992 and September and November 1993) (Fig. 2).

Comparisons of total counts in the bay with monthly means of penguins coming

Table 1. Numbers of penguins counted each month between April 1991 and August 1994. nc = not counted.

	1991	1992	1993	1994	Mean
Jan		11	13	12	12
Feb		19	20	0	13
Mar		21	10	78	36.3
Apr	202	66	81	214	140.8
May	105	181	89	138	128.3
Jun	118	52	nc	24	64.7
Jul	15	52	48	nc	38.3
Aug	5	nc	53	14	24
Sep	nc	2	121		61.5
Oct	22	183	28		77.7
Nov	0	4	126		43.3
Dec	9	88	nc		48.5

ashore at Summerland Beach on the southern shore of Phillip Island showed no significant correlation ($r = 0.31$, $df = 34$, $p > 0.05$). Similarly there was no significant relationship found between the counts of penguins in Western Port during the breeding period and the number of penguin burrows on Phillip Island containing eggs or chicks ($r = 0.09$, $df = 18$, $p > 0.05$). The absence of correlations between these variables suggests that the number of birds using Western Port is not related to attendance patterns or breeding activity on Phillip Island.

We attempted to estimate the total number of penguins frequenting Western Port by calculating the percentage of the bay covered by the counts and, assuming that the penguins were distributed in a representative manner on the transects, extrapolating from the mean and maximum counts accordingly. We also assumed that there were no penguins in the shallow parts of the bay and that the field of view was 500 m on either side of the transect. Both of the latter of these assumptions were tested in the field and found to be valid. No penguins were seen during extensive searches over intertidal areas of the bay at high tide on the first two surveys suggesting that these areas were not important feeding areas for penguins. In addition we experimented with penguin-sized objects floating on the sea's surface and found that these could be seen up to 500 m from the boat providing wind speeds were less than 15 knots. Calculated in this manner, we estimated that the total counts covered 55.8% (81 km^2) of the area of the bay judged as likely to be frequented by penguins (145.2 km^2). In April 1994, when the number of penguins counted in the bay was greatest (214), we estimate that the total number in the bay was 383 ($214 \times 100/ 55.8$). Similarly, the mean for all counts (57.4; Table 1) gave an estimate of 103 birds.

The seasonal pattern of penguin abundance in Western Port is illustrated by the monthly means of all counts (Fig. 3). Higher numbers of penguins were found in late autumn and winter and the lowest means were in mid and late summer.

The penguins were located mainly in the western and northern arms of the bay (Fig. 1). Relatively few birds were seen in the shallower eastern arm and none over intertidal areas. The highest numbers of penguins per kilometre of transect were found along two transects in the centre of the bay at the confluence of the western, northern and eastern arms (Fig. 1).

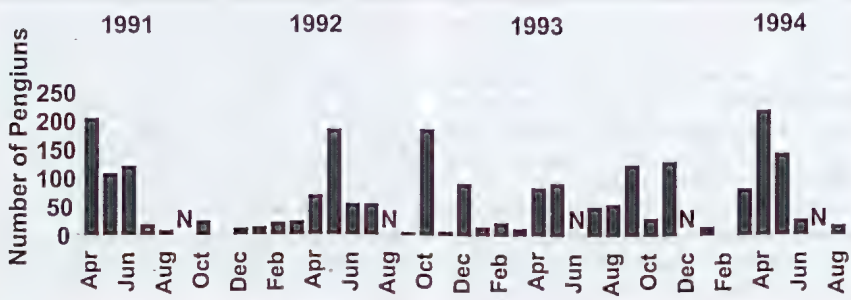

Fig. 2. The total numbers of Little Penguins counted each month in Western Port between April 1991 and August 1994. N denotes missing counts.

Table 2. Group sizes of Little Penguins recorded at sea in Western Port.

Group Size	Number of Groups	%
1	437	49.4
2	194	22.0
3	117	13.2
4	57	6.5
5	27	3.1
6	12	1.4
7	7	0.8
8	6	0.7
9	2	0.2
10	7	0.8
11	2	0.2
12	5	0.6
13	0	0
14	2	0.2
15	1	0.1
16	0	0
17	1	0.1
18	0	0
19	0	0
20	1	0.1
23	1	0.1
25	1	0.1
31	1	0.1
35	1	0.1
40	1	0.1
112	1	0.1
Total	**884**	**100**

Group sizes were small, 49% (437) of 884 groups consisted of single birds and 94% of groups consisted of five birds or fewer (Table 2). In October 1992, 112 birds were observed in one group feeding with terns and gulls at the confluence of the northern and western arms but groups of 20 birds or more were seen on only seven occasions.

Penguins were seen feeding in conjunction with terns and gulls on a number of occasions and these aggregations appeared to be associated with large schools of baitfish. Fig. 4 is an echosounding trace taken where penguins and Crested Terns *Sterna bergii* were feeding together and shows schools of baitfish that have apparently been driven to the surface by predatory fish (Frank Hoedt, *pers. comm.*) and hence made available to feeding seabirds.

Over the past 25 years there have been many reports of penguins on and around Barriliar Island to the north-west of French Island (Bird Observer's Club of Australia-Western Port Survey, *unpubl. data*). In March 1993 we visited the island and found one penguin chick almost at fledging age in one burrow, and one moulting adult in another. Two other empty burrows appeared to be in regular use. A second visit in March the following year revealed a similar number of burrows in use. This small group of breeding birds (probably eight in total) presumably accounted for the small number of penguins occasionally seen at the top of the north arm.

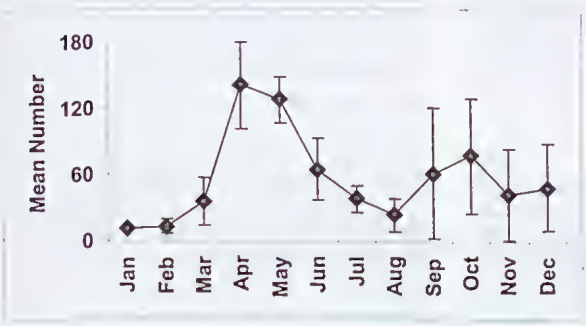

Fig. 3. The mean numbers (± S.E.) of Little Penguins counted each month in Western Port between April 1991 and August 1994.

Discussion

Significance of Western Port for Little Penguins

These surveys and recent radio-tracking studies (Collins *et al.* 1999) have shown that more penguins feed in Western Port than previous studies suggested. For example, none of the 67 penguins from Phillip Island that had been followed by radio-tracking between 1986-87 went into Western Port (Weavers 1992). This may have been because the birds that were radio-tracked by Weavers came from the southern side of the Summerland Peninsula rather than the northern side that faces Western Port (Dann *et al.* 1992). Similarly, none of the 413 penguins that were banded (with individually numbered flipper tags) on Phillip Island between 1968 and 1988 and found dead away from the Island, was found inside Western Port (Dann *et al.* 1992). Most of the shores of Western Port are mangrove-lined with

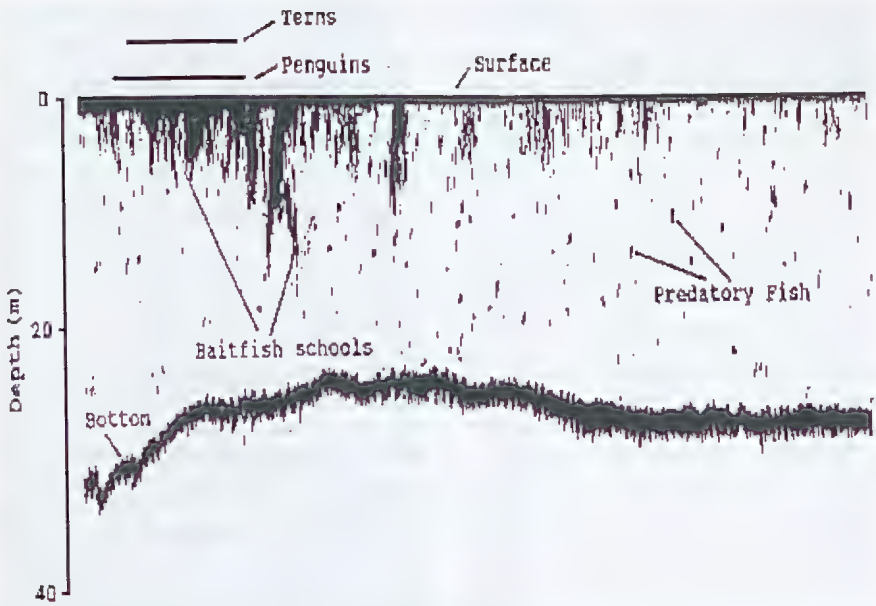

Fig. 4. An echosounding trace of baitfish schools that have been driven to the surface by predatory fish. The lower of the two horizontal lines above the sea surface represents where penguins were observed feeding in relation to the baitfish schools and the higher, Crested Terns *Sterna bergii*. Diagram and interpretation provided by Frank Hoedt.

extensive intertidal mudflats (Shapiro 1975) and it may be that beach-washed penguins (the major source of band recoveries away from Phillip Island) are rarely discovered in these areas.

The largest number of penguins using Western Port during this study was estimated to be 383 and the mean for all the estimates was 103 penguins. It is estimated that there are approximately 24-28,000 breeding penguins on Phillip Island (Mike Cullen, *unpubl. data*). Using the middle of this range (26,000), the estimated maximum number of birds in Western Port (383) was 1.5% of the breeding population on Phillip Island.

Distribution in Western Port

The western arm, and to a lesser extent, the northern arm, were the more important feeding areas for penguins in Western Port. Both this survey and radio-tracking studies (Collins *et al.* 1999) have highlighted the importance of the western arm to penguins in autumn, a reflection in part of the proximity of this part of the bay to the breeding colony. The high numbers per kilometre in the central part of the bay suggest that the availability of food may have been higher there. It may be that the mixing of different water masses at the confluence of the three arms of the bay creates conditions favourable to the prey species of penguins. The convergent fronts associated with tidal plumes have been identified as physical processes that may enhance seabird foraging (see Hawke 1996 and references therein). By contrast to penguins, observations of Australian Fur Seals *Arctocephalus pusillus* were fairly evenly spread throughout the bay and Bottlenose Dolphins *Tursiops truncatus* were found more frequently at the two entrances to Bass Strait (Dann *et al.* 1996).

The group size of penguins in Western Port showed some similarity to that reported for penguins seen at sea in Port Phillip Bay (Norman 1992a). In this study, 94% of groups consisted of five birds or fewer, and in Norman's (1992a) surveys, 93.7% of groups consisted of five birds or fewer (calculated from his Table 5). However twice as many birds were solitary in this study.

Seasonal occurrence of penguins in Western Port

Peak numbers occurred in April and May and lowest numbers in January and February. Brager and Stanley (1999) found peaks in abundance of White-flippered Penguins *Eudyptula minor albosignata* in inshore waters around the Banks Peninsula in New Zealand in autumn and spring also but had no information on prey abundance or distribution for comparison. Peak numbers of penguins in Western Port coincided with the latter part of the seasonal occurrence of juvenile pilchards and anchovies in the bay in late summer and autumn (Hoedt *et al.* 1995). The food supply of penguins between spring and autumn may be largely dependent on the appearance of spawning adult fish near Phillip Island (Cullen *et al.* 1992; Hoedt *et al.* 1995) and the subsequent pulse of young recruits (late summer and autumn) hatched from the spawning. The increased use of Western Port by penguins in autumn may be caused as much by the depletion of adult fish outside the bay as the arrival of juvenile fish inside the bay and hence not precisely reflect the timing of the latter event.

Acknowledgements

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New Tanjilian Fossil Localities at Dungaree Creek, Central Victoria

Clem Earp[1]

Abstract
Forestry work in the Matlock district, central Victoria, Australia, has temporarily revealed two new fossil localities in the Norton Gully Sandstone, Walhalla Group, of Pragian-Emsian (Early Devonian) age. The fauna, a 'Tanjilian' marine fossil assemblage of *Panenka* bivalve molluscs, dacryoconarids, and orthoconic nautiloids, is briefly described, and a summary of relevant literature is given. From qualitative and quantitative observations of the sedimentology, it is concluded that the fossils are allochthonous and were deposited by turbidity currents, with no sign of reworking by storm wave action. (*The Victorian Naturalist* **118** (3), 2001, 82-88.)

Introduction

The term 'Tanjilian' was coined by Chapman (1914, 1926) as a tentative name for a rock series characterised by a small set of distinctive fossils. The first of these had been described by McCoy (1879) from the Tanjil goldfield in west Gippsland. This location was lost and Gill (1941) renamed the series 'Jordanian', claiming that it did not occur in the Tanjil area at all.

Thomas (1953) reported the rediscovery of the original location, but further geological mapping has made the term obsolete as a stratigraphic name. The name now seems restricted to a subset of Chapman's original group of fossils, which form a distinctive assemblage in a Lower Devonian marine formation, the Norton Gully Sandstone unit of the Walhalla Group (VandenBerg 1975).

A Tanjilian assemblage typically contains three types of fossils:

- bivalve molluscs, usually belonging to the genus *Panenka*, although a few other genera are known;
- dacryoconarids, small conical-shelled planktonic animals, referred to in older literature as tentaculites and pteropods;
- orthoconic (straight-shelled) nautiloids.

Brachiopods, so characteristic of the Victorian Devonian, do not occur in the assemblage but are common enough in other horizons of the Norton Gully Sandstone. Conversely, the Tanjilian species seldom occur outside this assemblage. A notable exception is the occurrence of the Tanjilian dacryoconarid *Nowakia* in limestone at Tyers River (Cooper 1973).

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Dungaree Creek fossil localities

The Warburton-Woods Point road closely follows the old Yarra Track after it passes Monty's Camp 70 km east of Warburton. The area contains several important Palaeozoic fossil localities, among which may be mentioned the 19-Mile Quarry (type locality of *Baragwanathia longifolia*; Lang and Cookson 1935), Mt. Matlock (Ordovician and Silurian graptolites; Harris and Thomas 1947), and Frenchman Spur (Early Devonian plants; Tims and Chambers 1984).

The road runs along the crest of the Great Dividing Range at an altitude of 1000 m. The district is unpopulated, hilly, and covered almost completely by a forest of Alpine Ash *Eucalyptus delegatensis* with an undergrowth of *Acacia* and *Coprosma* species and Blanket Leaf *Bedfordia arborescens*. The bush and a soil cover of up to 2 m mean that rock exposures are limited solely to areas of human disturbance, such as roads and former building sites.

In 1994 I noticed a new logging track which did not appear on any maps (Fig. 1). It is 1.2 km east of Fehring's Clearing, and branches northwest off the main road just past where the road crosses the head of Dungaree Creek. The track follows a ridge for about 0.75 km, then emerges into a burnt clearing (now overgrown).

Bedrock is first exposed about 0.4 km along the track, on the ridge separating Dungaree and Oaks Creeks. For the next 0.3 km, the strata are visible in the surface of the bulldozed track, dipping 75° west and striking 135°. The rock is weathered and relatively soft, and consists of yellow

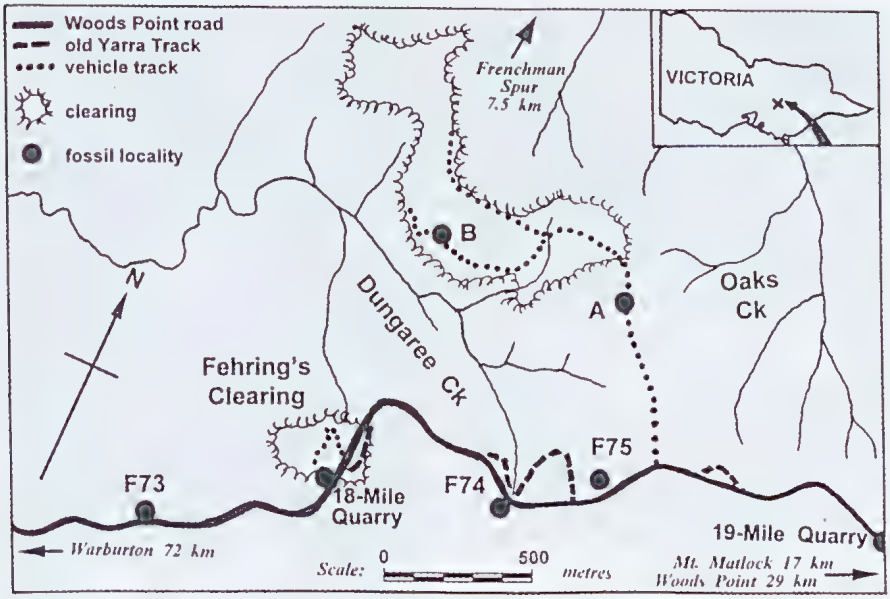

Fig. 1. Locality map, Dungaree Creek area. Fossil localities: A, B - this paper; F73, F74, F75 - spot localities of Moore (1965); 18-Mile Quarry and 19-Mile Quarry according to Geological Survey of Victoria (Talent 1968). Map drawn from aerial photograph (1995) supplied by Qasco Pty. Ltd.

and black thin-bedded claystone, siltstone, and fine to coarse sandstone.

At one particular point, designated location A (Fig. 1), loose blocks of the bedrock have been unearthed, and coarser material is evident. Sandstone, weathered pink and yellow, is interbedded with the finer sediments, and all contain abundant comminuted plant fragments. Most are preserved as mineralised impressions, but some coalified remains were found. A single sandstone block was found to contain a typical Tanjilian fauna.

At a fork in the track, a low cutting exposes red sandstone speckled with mica. The west branch of the track is bulldozed out of the thick soil cover, which contains loose stone blocks. In the area where this branch of the track turns to the northwest, the blocks are a silvery sandstone, in which mica is the main component. The bedding planes in these blocks are crowded with comminuted plant impressions, but because of the lack of mineralisation or remnant carbon, and the coarseness of the medium, none are identifiable. The source of the mica is unknown; possibly the material is reworked from older sedimentary rocks.

Further on, the track winds round the side of a small valley, and the area is heavily churned by logging machinery. Loose blocks of graded coarse sediment contain well-rounded quartz particles ranging up to small granule size (2 mm diameter). The only in-place exposure is thin-bedded grey mudstone; the dip and strike indicate hillside creep. On the side of the hill near here were found loose blocks of yellow and grey thin-bedded claystone to sandstone containing a well-preserved Tanjilian assemblage; this is designated location B (Fig. 1).

A collection in the Museum of Victoria, made by G. Bell near Mt. Duffy almost exactly 20 km north of Dungaree Creek, shows precisely the same lithology and fossil assemblage as location B.

Previous studies

The references cited previously are all relevant to the general Yarra Track area. A useful list of all the early fossil localities has been compiled by Bell (1956). However, faulting is present, and sudden lithological changes occur, so that the particular interval of rock observed at Dungaree Creek is very unlikely to be the

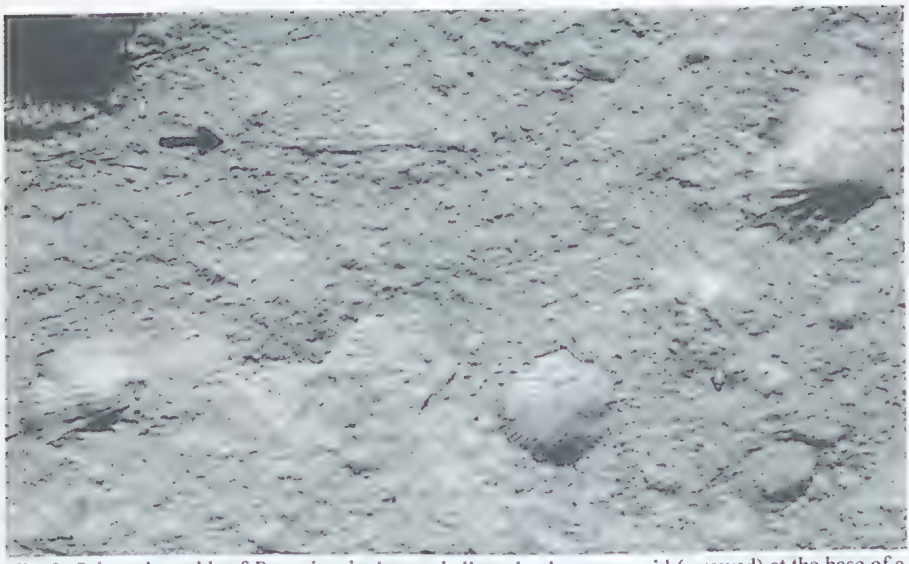

Fig. 2. Oriented moulds of *Panenka planicosta* shells and a dacryoconarid (arrowed) at the base of a sandstone turbidite layer. Location B, ×4.5. The arrow points down current.

same as that at 19-Mile Quarry or Frenchman Spur, for example.

Gill (1941) listed a number of fossil localities in the area. At the closest of his localities, the 18-Mile Quarry, he recorded the typical Tanjilian assemblage of bivalves (*Panenka gippslandica*), dacryoconarids (*Styliolina fissurella* and '*Tentaculites*') and orthoceratid nautiloids, as well as the plants *Zosterophyllum australianum* and *Hedeia corymbosa*. The dacryoconarids were re-examined by Boucek (1968, as 'locality 60216'), who identified several other taxa, but some of these were disputed by VandenBerg (1975). Recent revisions of dacryoconarid species have altered many of these identifications (Alberti 1988, 1993, 1995, 1997, 1998).

Moore (1965) attempted a detailed description of the area from Warburton to Woods Point, but his observations were limited to road cuttings and his stratigraphy is regarded as unreliable (VandenBerg 1975). His record of fossils from his location F75, which he equates with the 18-Mile Quarry, includes Gill's earlier collection, with the addition of the bivalve *Panenka planicosta*. Also from this location, and from two others nearby (F73 and F74, see Fig. 1), Moore added '*Hostimella*', and 'plant remains indet.', terms which are really synonymous. It is important to note that the location shown on Moore's map for the 18-Mile Quarry does not match that on the later Geological Survey maps (Talent 1968; VandenBerg 1975; Fig. 2).

The area was more closely examined towards the early 1970s in connection with the Thomson Dam scheme. Talent (1968) emphasized the importance of allowing for considerable hillside creep when measuring dips and strikes. Tapp's thesis (1970) largely follows Moore. VandenBerg's preliminary stratigraphy (1971) contains some interesting sections; some of the nomenclature was published (VandenBerg and Schleiger 1972). The definitive stratigraphy is set out in VandenBerg's final report (1975); this makes it clear that the 18-Mile Quarry and the new exposures all lie in the lower part of the Norton Gully Sandstone.

Palaeontology

Only the fauna is discussed here, as none of the abundant plant remains are identifiable. The fossils of the Tanjilian fauna at Dungaree Creek are represented by moulds, with no calcareous shelly matter remaining.

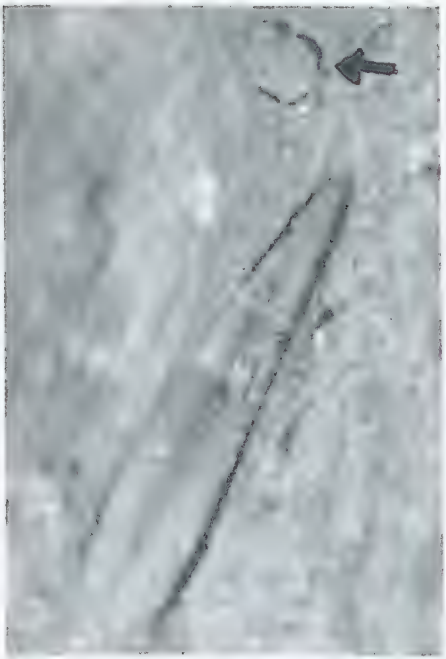

Fig. 3. Crushed mould of one dacryoconarid shell in longitudinal view, and another (arrowed) in transverse view, in shell breccia siltstone. Location B, ×26.

***Panenka* bivalve molluscs**

Phylum Mollusca – Class Bivalvia – Subclass Pteriomorphia – Order Praecardioida – Family Praecardiidae – Genus *Panenka*

Panenka planicosta Chapman 1908

Well-preserved moulds of single valves of this species (Fig. 2) were found at location B. Unlike other Victorian *Panenka*, which have medium to large shells, this species is under 5 mm in diameter. The radial ribs, when viewed under a magnifying glass, have a groove along their length and this distinguishes them from juvenile specimens of the larger species. Members of the genus are said to be deep-water molluscs burrowing shallowly in a soft sea floor (Kríz 1979).

Interspersed among the *Panenka* are poorly-preserved minute smooth shells, up to 0.7 mm diameter. These are presumed to be the spat (juveniles) of *P. planicosta*; the association of smooth juveniles and ribbed adults is similar to other bivalve occurrences (e.g. Pojeta *et al.* 1976, Plate 2, fig. 4). The same small shells are seen at location A without the adults.

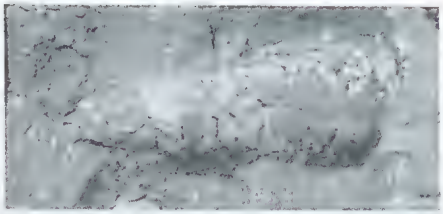

Fig. 4. Poorly preserved mould of the uncrushed apical portion of a nautiloid. Location A, ×2.

Dacryoconarids

Phylum Mollusca – Class Tentaculitoidea – Order Dacryoconarida

The dacryoconarids are fossil remains of small, narrow conical shells (Figs 2, 3), usually appearing in crushed form as narrow isosceles triangles with a prominent longitudinal fracture that was once erroneously thought to be a characteristic of the live animal. As the dacryoconarid animals were planktonic, they spread freely over the mid-Palaeozoic seas, and can be used to correlate and date strata from different continents. Most Tanjilian forms are classed as either styliolinids, with smooth or longitudinally striated shells (Gill 1941), or nowakiids, with prominent transverse rings (Cooper 1973).

Family Styliolinidae – Genus *Styliolina*

Styliolina cf. *fissurella* (Hall)

Smooth-shelled Tanjilian dacryoconarids are assumed to belong to this species, which can be distinguished from the other Victorian styliolinids *Metastyliolina* (with longitudinal ribs) and *Styliacus* (with very narrow shells) (Alberti 1988).

This species of *Styliolina* would, by international comparisons, date the Dungaree Creek localities as Emsian or younger (Boucek 1968), i.e. latest Pragian to Zlichovian in the Bohemian stages. However, the situation is not quite so clear as that. In Victoria, *S. fissurella* has been reported from a wide range of localities (Garratt 1975), often in conjunction with typically Pragian fossils, but ranging down to the base of the Humevale Siltstone at Lilydale, which is supposedly of earliest Lochkovian age. Elsewhere, *S. fissurella* has been reported from Alaska (Churkin and Carter 1970) and Central Asia (Obut 1974) from the same graptolite zones of the Pragian-Emsian as are found in the

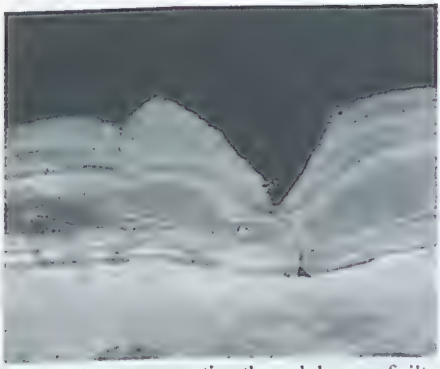

Fig. 5. Transverse section through layers of siltstone and claystone which have been deformed underneath a single detached chamber of a nautiloid shell resting at the base of an overlying sandstone bed (now removed). Location A, ×3.

lower Norton Gully Sandstone. On the other hand, Boucek (1968) suggested that the dacryoconarids from 18-Mile Quarry were much younger: Eifelian (Middle Devonian), as they are in Europe. The difference arises, at least in part, from the nondescript nature of the fossils, which prevents discrimination of taxa from different periods. On account of the association with Pragian fossils, it is preferable to consider the Victorian occurrences as being contemporaneous with those in Alaska and Central Asia rather than those in Europe.

Family Nowakiidae – Genus *Nowakia*
Nowakia ex gr. *acuaria* (Richter)

These are too fragmentary to identify precisely. Moreover, the minute rings have often become very faint, suggesting the possibility that some of the apparent styliolinids are poorly preserved nowakiids. Alberti (1995) considers Tanjilian specimens to be an indeterminable subspecies of *N. acuaria* at lower levels, succeeded by *N. matlockiensis* (Chapman). The age ranges he gives for these species are late Pragian - early Emsian. The specimens from Dungaree Creek belong to the *acuaria* species group, lacking the density of fine rings seen in *N. matlockiensis*.

Orthoconic nautiloids

Phylum Mollusca – Class Cephalopoda – Subclass Nautiloidea – Order Orthocerida – Superfamily Orthoceratoidea – Family Orthoceratidae – Genus *Michelinoceras*
Michelinoceras sp. indet.

Sections of conch found at location A in fine-grained pink sandstone. These show a circular cross-section, empty central siphuncle, and a relatively wide septal separation. The remains are commonly referred to in Victorian literature as '*Orthoceras*', however this genus has long been restricted to a few species of Ordovician age. Modern standards of diagnosis practically rule out any hope of identifying leached-out specimens like these, as most internal structures have been destroyed. The surviving characteristics mentioned above are consistent with the genus *Michelinoceras*, which is, indeed, where many former '*Orthoceras*' species are now assigned.

In contrast to the thin-shelled dacryoconarids, which are mostly crushed, the nautiloid sections are intact (Fig. 4). The pressure of overlying sediments has instead pushed them down a little, slightly distorting the underlying layers (Fig. 5).

Sedimentology

Recent studies of the Walhalla Group, outside the Matlock district, have suggested that the sediments were deposited in relatively shallow water and reworked by storm waves (Weir *et al.* 1988; Dyson 1996). Previously, deep-water turbidity currents were considered responsible for the sedimentation (VandenBerg and Schleiger 1972). Insufficient exposures are available to allow study of purely sedimentary structures at Dungaree Creek, but the appearance of the fossil remains do permit some conclusions to be drawn.

The Tanjilian assemblages occur in two modes: as chaotically arranged three-dimensional shell breccia, and as oriented shells lying on a single plane. Both contain only disarticulated bivalves. Moore (1965) was of the opinion that bands of shelly Tanjilian fossils represented mass mortality episodes caused by turbidity. From the appearance of the *Panenka* it would seem the shells are the transported remains of already disarticulated animals. The association of mineralized comminuted plants and small molluscs resembles the 'dysoxic' facies of Mapes and Mapes (1997), formed by rapid sedimentation at depth.

The shell breccia forms irregular layers

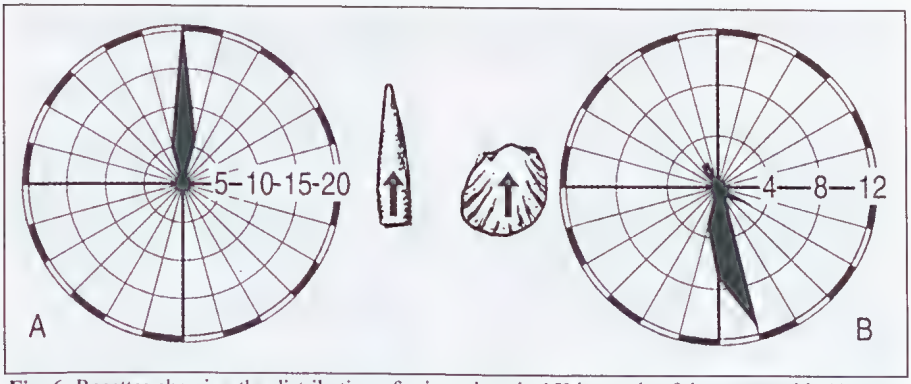

Fig. 6. Rosettes showing the distribution of orientations in 15° intervals of dacryoconarids (A, sample size N=31) and *Panenka* (B, N=27). The orientation conventions used for the measurements are those of Nagle (1967), shown by the arrows with the small drawings of each shell type. From the bedding plane part of which is shown in Fig. 2; as the slab was not in place, absolute directions could not be used; the measurements are relative to the mean orientation direction of the dacryoconarids.

in massive siltstone. *Panenka* valves are oriented at all angles with respect to the bedding and to each other. Dacryoconarids are also oriented at angles to the bedding (Fig. 3), indicating rapid, turbulent deposition (Hladil *et al.* 1996). There are rare tabular rip-up clasts of shale. These observations suggest rapid deposition from a dense turbidity current.

The layers of oriented fossils seem to form at the junction of a breccia layer with an overlying band of fine sandstone, and probably represent reworking of the breccia by current scouring. *Panenka* valves all rest concave side down, and dacryoconarids lie on their sides (Fig. 2). As cleavage is planar at the base of the sandstone, it is possible to measure the longitudinal orientation of the shells using the plastic sheet method (Schleiger 1969). The results are shown diagrammatically in Fig. 6, and may be compared with the classic findings of Nagle (1967) on the differences between wave and current orientation. The unimodal orientation of the conical dacryoconarids unambiguously indicates current action, and this is supported by the strong orientation of the *Panenka*, even though it is of a shape which Nagle found to be relatively insensitive to currents.

The absolute palaeocurrent direction cannot be determined from the material available. Tapp (1970) recorded currents from due west at a number of Tanjilian localities, and this is consistent with recent, more accurate measurements from more distant localities of the Norton Gully Sandstone along the same structural trend as the study area (Powell *et al.* 1998).

Conclusions

The sediments at Dungaree Creek are of late Pragian or early Emsian age. The presence of coarse sandstone, and the orientation of the fossils, indicate turbidity currents; there is no evidence of wave action from the limited observations. Soft-sediment deformation under hard fossils, preservation of abundant plant remains, reworking and random orientation of shell breccia all indicate a period of rapid deposition.

Acknowledgements

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Addendum to 'Moss Collections from Lord Howe Island in the National Herbarium of Victoria (MEL)'

Josephine Milne[1] and Arthur W. Thies[1]

Abstract
Plagiothecium howeanum Müll.Hal. *ex* Jaeger, *nomen nudum* is *Ectropothecium leucochlorum* (Hampe) Broth., the spelling of which is corrected. (*The Victorian Naturalist* **118** (3), 2001, 89-91.)

Hampe (1874) described a new species, *Drepano-hypnum leucochlorum*, from Lord Howe Island. This grammatically correct specific epithet ending is repeated in Hampe (1880), with the citation of *Hypnum* (Sect. *Drepano-Hypnum*) *leucochlorum*. According to the International Code of Botanical Nomenclature, this original spelling of the epithet must stand.

Mitten (1883) introduced the combination *Stereodon leucochlorum* (sic) (Hampe) Mitten. Paris (1904, p. 54) refers to the name *Hypnum leucochloron* (Hampe) Jaeger with *Drepano-Hypnum leucochloron* and *Stereodon leucochlorus* as synonyms. Brotherus (1908) transferred the species to *Ectropothecium*, as *E. leucochloron* (Hampe) Broth.

The name *Plagiothecium howeanum* was published without description as a *nomen nudum* by Jaeger (1878), attributed to Müll.Hal., citing 'Lord Howe's Island ad truncos (*Fullager* [sic])'. There is a collection identified as this species from Lord Howe Island collected by Fullagar (the correct spelling) at MEL (MEL 32391), and is likely to be the material referred to by Jaeger. Although there are no other collections in other Australian herbaria, duplicates may exist elsewhere. In any case, the specimen has no formal status as type since the name was not validly published. The collection (MEL 32391) also contains a label 'Platy-Hypnum Howeanum C. Müller', apparently in Hampe's hand (Thies (2000) incorrectly cited the label as 'Cyrto-Hypnum howeanum C.M.').

Thies (2000) suggested, on the basis of MEL 32391 that *P. howeanum* 'seems to be a good species'. However, further examination of the material has shown that MEL 32391 is actually *Ectropothecium leucochlorum* (Hampe) Broth., and agrees with several other collections of Fullagar's, correctly identified. The species was subsequently collected on Lord Howe Island by W.W. Watts in 1911 (c. 40 collections – specimens in NSW) and more recently by D.H. Vitt, in 1981, (specimen in CANB; dupl. in ALTA).

Ectropothecium leucochlorum, which is endemic to Lord Howe Island, is a small, delicate moss with a creeping habit (Fig. 1a). It often has numerous side branches on which perigonia (male reproductive structures) usually occur. The stems and branches are c. 0.1 mm diameter and in cross-section the stem consists of outer stereid cells (small thick-walled cells), a core of wide cells, and lacks a central strand (Fig. 1b). Delicate filamentous or two cell wide hyaline (colourless) pseudoparaphyllia (minute filaments borne on the stem) occur at the base of branches (Fig. 1c-d). Leaves are non-decurrent (with leaf margins not extending down the stem below the point of insertion), generally spirally inserted and branch leaves are somewhat smaller than stem leaves. The leaves are narrowly obovate-acuminate (Fig. 1e), occasionally falcate (sickle-shaped leaf tip) (Fig. 1f), lack a nerve and the leaf margin is entire (Fig. 1e). Leaf cells are smooth, linear and thin-walled (Fig. 1g), and those at the basal corner of the leaf (alar cells) can vary from undifferentiated to greatly inflated (Fig. 1h). The sporophyte occurs on the main stem and the seta (c. 0.6-1.6 cm) is red, smooth and twisted to the left. The capsule lacks stomata and an annulus (specialized ring of cells around the rim of the capsule mouth). The peristome (teeth at capsule opening) is double and spores are 10-12 μm diameter.

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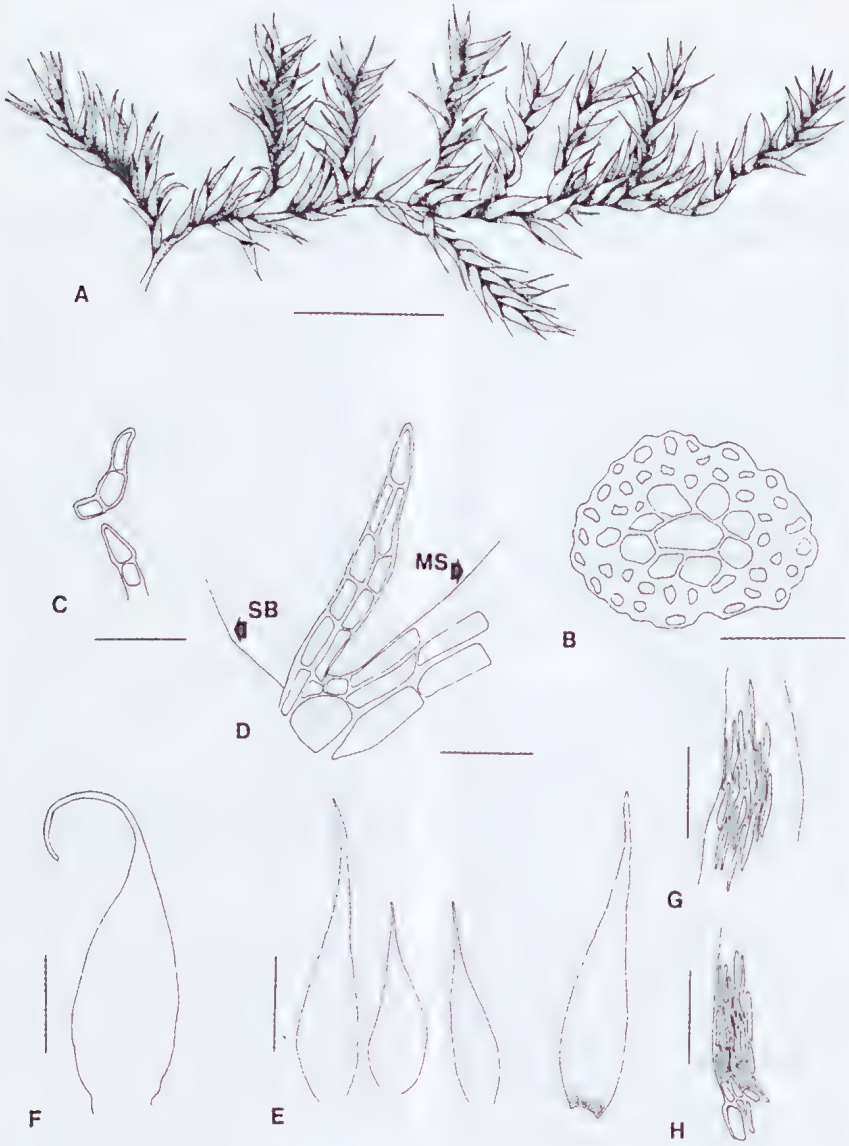

Fig. 1. MEL 32391. a) Plant habit; b) stem cross-section; c)-d) pseudoparaphyllia at origin of branches (MS = main stem, SBR = side branch); e) stem and branch leaves; f) falcate leaf; g) lamina cells at mid leaf; h) cells near stem insertion. Scale bars a) 2 mm, b)-d) 50 µm, e)-f) 300 µm, g)-h) 250 µm.

Acknowledgements
We thank an anonymous reviewer who pointed out the true affinity of the specimen labelled as *Plagiothecium howeanum* with *Ectropothecium*; Prof. R.D. Seppelt and Dr T. May for their valuable comments, Dr. A. Veenstra-Quah for assistance with the figures, the curator of NSW for the loan of herbarium specimens and staff at AD, BRI, CANB, HO and PERTH for checking holdings of herbarium specimens of this species.

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Flora and Fauna Guarantee Act 1988

The Flora and Fauna Guarantee Scientific Advisory Committee has made recommendations in relation to nominations for listing under the provisions of the ***Flora and Fauna Guarantee Act* 1988**. The following reports have been received:

Species/Process/Community		Recommendation
Final Recommendations		
Acacia phasmoides	Phantom Wattle	Supported
Acacia phlebophylla	Buffalo Sallow Wattle	Supported
Acianthus collinus	Inland Pixie Caps	Supported
Aprasia striolata	Striped Worm-lizard	Supported
Babingtonia crenulata	Fern-leaf Baeckea	Supported
Caladenia sp. aff. *venusta*	Kilsyth South Spider-orchid	Supported
Caladenia carnea var. *subulata*	Striped Pink Fingers	Supported
Caladenia colorata	Painted Spider-orchid	Supported
Caladenia cruciformis	Orchid spp.	Supported
Caladenia insularis	French Island Spider-orchid	Supported
Caladenia pilotensis	Mt Pilot Spider-orchid	Supported
Caladenia valida	Robust Spider-orchid	Supported
Caladenia versicolor	Candy Spider-orchid	Supported
Calomnion complanatum	Tree-fern Calomnion	Supported
Chthonicola sagittata	Speckled Warbler	Supported
Engaeus rostrogaleatus	Strzelecki Burrowing Cray	Supported
Egernia coventryi	Swamp Skink	Supported
Gaultheria hispida	Snow-berry	Supported
Litoria booroolongensis	Booroolong Frog	Supported
Litoria raniformis	Warty Bell Frog	Supported
Litoria verreauxii alpina	Alpine Tree Frog	Supported
Macronectes giganteus	Southern Giant-Petrel	Supported
Macronectes halli	Northern Giant-Petrel	Supported
Melanodryas cucullata	Hooded Robin	Supported
Megaptera novaeangliae	Humpback Whale	Supported
Neuropogon acromelanus	Lichen spp.	Supported
Nyctophilus timoriensis	Eastern Long-eared Bat	Supported
Oreoica gutturalis	Crested Bellbird	Supported
Peronomyrmex 'bartoni'	Ant sp.	Supported
Persoonia asperula	Mountain Geebung	Supported
Prasophyllum fosteri	Foster's Leek-orchid	Supported
Prasophyllum morganii	Cobungra Leek-orchid	Supported
Prasophyllum niphopedium	Marsh Leek-orchid	Supported
Pratia gelida	Snow Pratia	Supported

Species/Process/Community	Recommendation	
Final Recommendations (cont.)		
Pseudocephalozia paludicola	Liverwort	Supported
Pteropus poliocephalus	Grey-headed Flying-fox	Supported
Pterostylis aenigma	Enigmatic Greenhood	Supported
Pultenaea lapidosa	Mt Tambo Bush-pea	Supported
Spyridium nitidum	Shining Spyridium	Supported
Stagonopleura guttata	Diamond Firetail	Supported
Struthidea cinerea	Apostlebird	Supported
Thelymitra hiemalis	Winter Sun-orchid	Supported
Thelymitra gregaria	Balsalt Sun-orchid	Supported
Thunnus maccoyii	Southern Bluefin Tuna	Supported
Xanthoparmelia suberadicata	Foliose Lichen	Supported
Victorian temperate-woodland bird community	Listed as a community	Supported
The introduction and spread of the large earth bumblebee *Bombus terrestris* L. into Victorian terrestrial environments	Potentially Threatening Process	Supported
Loss of terrestrial climatic habitat caused by anthropogenic emissions of greenhouse gases	Potentially Threatening Process	Supported
Preliminary Recommendations		
Euastacus neodiversus	South Gippsland Spiny Cray	Supported
Gramastacus insolitus	Western Swamp Cray	Supported
Hyridella glenelgensis	Glenelg Freshwater Mussel	Supported
Prasophyllum sp.	Swamp Leek-orchid	Supported

Copies of all reports are held in the FNCV library. Recommendation reports will be available on NRE's web page (http://www.nre.vic.gov.au).

A New Zealand Hepatic in Victoria

The leafy liverwort *Pedinophyllum monoicum* (Stephani) Grolle, until now thought to be a New Zealand endemic, has been found in cool temperate rainforest in the Yarra Ranges National Park, near Marysville. The specimen was collected from rotting wood and soil by Alex McLean of Monash University, while studying the bryophytes of Myrtle Beech *Nothofagus cunninghamii* forest. The identity was confirmed by David Glenny, Landcare Research New Zealand.

Although a member of the family Plagiochilaceae, *P. monoicum* is at first glance very similar to the common liverwort *Chiloscyphus semiteres* (formerly *Lophocolea semiteres*). However, *P. monoicum* has no underleaves, and there are copious rhizoids on the ventral surface on the lower parts of the stem. It is the only species in the genus that occurs in Australasia (Schuster 1963). It is described in Grolle (1960), Inoue and Schuster (1971) and Allison and Child (1975).

It is possible that this species will be found elsewhere in Victoria, and in Tasmania. For the present it must be considered to be endangered (ROTAP category 1E) in Australia, according to the criteria set out in Scott *et al.* (1997). Under the criteria currently used in Victoria it might also be classified as endangered in the State (D. Cameron, NRE Victoria, *pers. comm.*), but no formal assessment of its conservation status has been made.

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Effects of Grazing, Tourism and Climate Change on the Alpine Vegetation of Kosciuszko National Park

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Abstract

Activities in the past (grazing), present (tourism) and future (tourism and potential climate change) have documented or potential long-term impacts on the biologically significant alpine flora of Kosciuszko National Park, Australia. The management of these activities provides insights for the conservation of fragile ecosystems in the Australian Alps, and for other high use, high conservation-value reserves. Grazing caused widespread damage that has required expensive, ongoing revegetation, the costs of which have been borne by publicly funded conservation organisations. The increasing use of the area by summer tourists has also caused severe but more localised damage to the vegetation, that can largely be controlled and reduced by effective management of tracks, visitors and weeds. Management of the most recent threat, climate change, requires a holistic approach including lobbying for a reduction in greenhouse gas emissions. The predicted changes in climate may result in a sequence of changes in the distribution of the native alpine plant communities, including an increase in the diversity and abundance of alien plants. (*The Victorian Naturalist* **118** (3), 2001, 93-99.)

Introduction

The impact of human activities on vegetation communities has reached critical levels in many natural systems. These include alpine regions where human activities have resulted in long-term damage or irreversible change (Mosley 1989; Good and Grenier 1994; Bakker and Berendse 1999). This is, in part, the result of the limited capacity that some alpine environments have to recover from disturbance, due to the low energy of the system and resultant slow growth rates for vegetation (Costin *et al.* 2000; Jacobs 1992). Human-induced damage to alpine vegetation has jeopardised water quality in catchments, indigenous communities, sustainability of the harvesting of natural resources and mountain tourism (Cullen 1992; Williams and Costin 1994).

The largest contiguous alpine region (taken here to only include vegetation above 1830 m) in Australia is centred around Mt Kosciuszko in the south east of New South Wales (Fig. 1).

This area of 122 km^2 has been subjected to a range of harmful human activities despite the international biological significance of the area (Good 1992a). The unique qualities of Kosciuszko National Park led to its inclusion in the UNESCO Man and the Biosphere Program in 1977, as an International Biosphere Reserve (Good 1992a). The region was classified as an outstanding example of an alpine and subalpine environment, which contains unique communities, and areas of unusual natural features of exceptional interest. Human activities pose a threat to these qualities unless effectively managed.

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Impacts of human activities

Grazing

Grazing was the first human activity to substantially alter the vegetation of the alpine region of Kosciuszko National Park (Table 1). Until the arrival of cattle and sheep, the flora had not experienced trampling by heavy, hard-hoofed animals (Good 1995). Grazing commenced in the 1830s and stock numbers were often high and ineffectively managed (Costin *et al.* 2000). The pressure of grazing was far beyond the capacity of the vegetation to sustain even seasonal usage (Good 1995). Decrease in vegetation cover, reductions in palatable species and changes in vegetation patterns and communities occurred (Helms 1893; Byles 1932; Costin 1954; Costin 1958; Costin *et al.* 1959; Costin *et al.* 1960; Bryant 1971; Good 1992a). The combination of regular intense grazing and the frequent use of fire as a management tool also led to severe sheet erosion, a legacy that remains with the park today (Bryant 1971; S.W. Johnston, *pers. comm.* 2000).

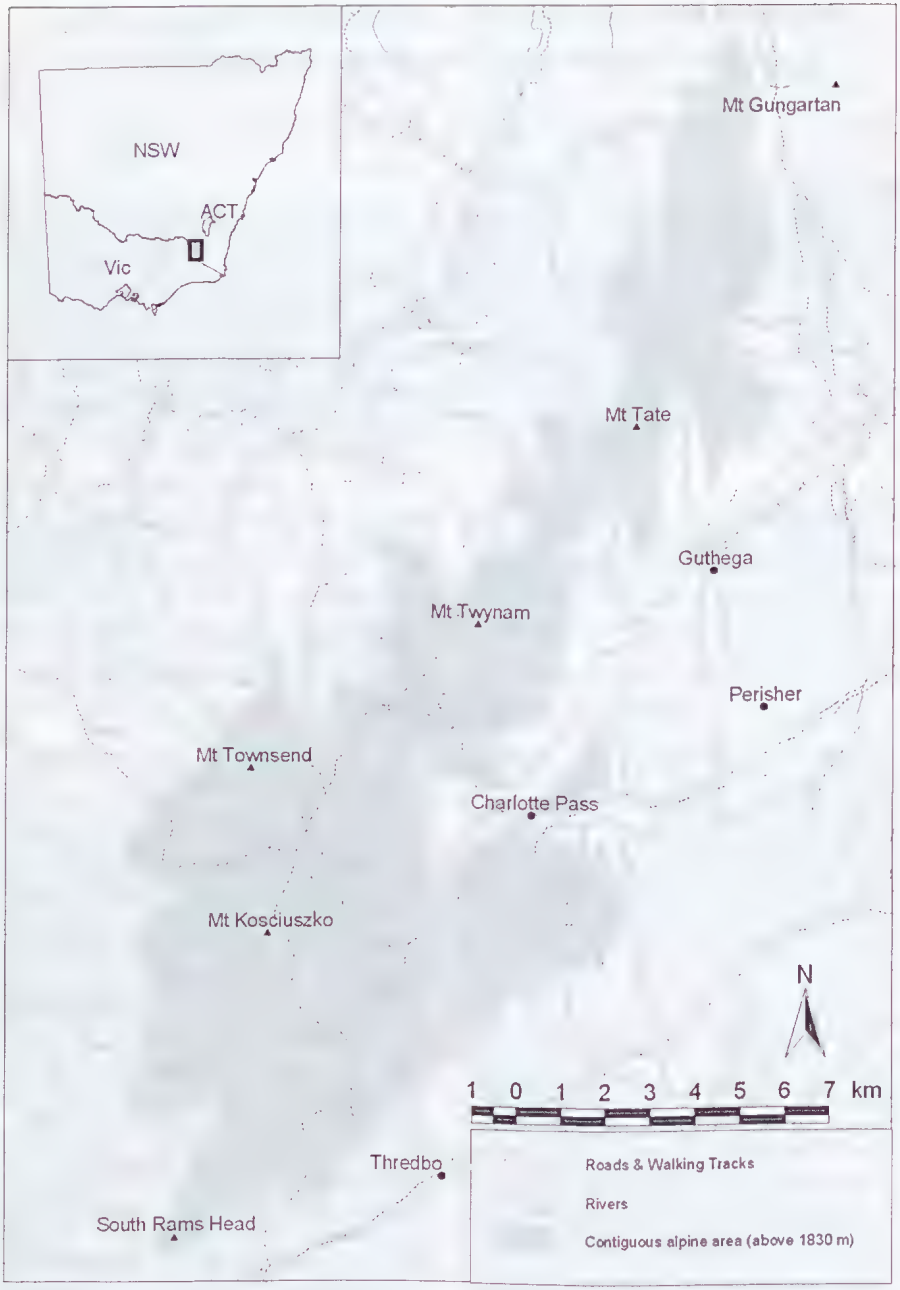

Fig. 1. Contiguous alpine area covered in this study around Mt Kosciuszko in Kosciuszko National Park, New South Wales, Australia.

The establishment of the Kosciusko State (later National) Park in 1944 and the start of the Snowy Mountains Hydroelectric Scheme in 1949 were the major factors that eventually led to the cessation of grazing in the Kosciuszko alpine area (Clark

1992; Good 1995). With the commencement of the hydroelectric scheme, the control of soil erosion and careful management of alpine catchments became crucial (Costin 1958; Costin and Polach 1971). Grazing leases were progressively withdrawn until in 1969, all grazing in what had become Kosciusko National Park was banned (Stanley 1982; NSW NPWS 1988). In 1957, a 25-year plan to revegetate and restore badly eroded areas commenced (Clothier and Condon 1968; Keane 1977; Clark 1992) and the most severely damaged lands were rehabilitated and revegetated. Although most of the revegetation works appeared to be successful at the time (sometimes after several treatments), there is now renewed erosion within these areas requiring more expensive rehabilitation (S.W. Johnston, *pers. comm.* 1999).

Grazing in the alpine zone highlights two general management issues. First, that damage to fragile ecosystems can have long term conservation and financial costs that greatly exceed the benefits of the original activity. Rehabilitation and stabilisation of the area cost in the order of A$4796 per hectare (A$2500 in 1984; Good 1995), considerably outweighing the benefit of the area as summer pasture (about A$10 to A$40 per hectare per annum, depending on method of estimation; values from Costin (1966) adjusted to 2000 values).

The second issue is that rehabilitation costs are often borne by organisations differing from those responsible for the original damage. In this case, rehabilitation was the responsibility of the publicly funded NSW Soil Conservation Service, and currently is the responsibility of the NSW National Parks and Wildlife Service. Therefore the benefits of grazing went primarily to private individuals, while the costs of repairing the damage resulting from the impacts of that activity was, and still is, borne by the public.

Tourism

With the end of grazing, tourism became the major issue for management in the alpine zone (Good 1992b; Buckley *et al.* 2000). As a result of increasing visitation, it is forecast that permanent and irreversible changes to the vegetation will occur (Table 1, Good 1995). Visitor numbers have increased with improved access to the area (Good 1995), increased public interest and environmental awareness (Mercer 1992) as well as efforts of the adjacent subalpine winter resorts to diversify and promote summer activities (Good 1995; König 1998). In the late 1970s, up to 1000 people per day visited the alpine zone (Edwards 1977). Currently over 2000 people per day visit the area during the peak holiday periods (S.W. Johnston, *pers. comm.* 1999).

The main tourist activities are walking, sightseeing and camping during summer and snowboarding and cross-country skiing in winter (Table 1). Impacts of tourism on the vegetation include trampling, introduction and spread of weeds, fire scars, littering, nutrient supplementation of soils and water, and the illegal collection of plants (Willard 1970; Liddle 1975; Cole 1985; Good and Grenier 1994; Good 1995; Zimmermann 1998; Buckley *et al.* 2000). To date, trampling and weeds appear to have had the greatest impact on the alpine vegetation (Edwards 1977; Mallen-Cooper 1990; Good 1992a).

The response by park management to erosion problems on tracks and trails has been the hardening of walkways with gravel, gravel within a plastic soil containment grid, raised wood or metal walkways, and pavers, along with controlled drainage lines (Good and Grenier 1994; CDT 1996). These management practices are expensive, with the rehabilitation of the summit area of Mt Kosciuszko and the surrounding area costing more than A$420,000 (NSW NPWS 1997). The most effective measure in terms of vegetation protection appears to be the construction of raised walkways. These reduce the physical contact of visitors with the flora, limit trampling and associated erosion and prevent the formation of multiple tracks particularly through bog and fen communities (Parr-Smith and Polley 1998). Raised walkways can also reduce weed establishment along track edges, because the introduction of gravel and sand is rarely necessary. Rehabilitation of track edges and other areas is an ongoing process using native seed and tube stock, mulch, fertiliser and plastic webbing (Terra Mat) at an overall cost of around A$119 per metre square (1997 values;

Table 1. Summary of human activities and effects on the vegetation of the alpine area of Kosciuszko National Park, Australia.

	Grazing	*Tourism*	*Climate change*
Timescale	100 years (ceased)[1]	1930s to present[2]	30-70 years in future[3]
Activities	Grazing[4] Burning Trampling Direct modification of drainage Deliberate and accidental establishment of introduced plants and animals	Walking on and off formal trails[5] Sightseeing Camping Rock climbing Cross country skiing/snowboarding Support and rescue vehicles	Direct: Alteration to temperature, precipitation and duration of snow cover[6] Increased length of exposure to high levels of UV light[7] Indirect: Alteration to competitive ability of different species of plants[8]
Problems	Vegetation loss[9] Soil exposure Soil erosion Spread of introduced plants	Changes in vegetation density and native species diversity[10] Trampling Collection of plant material Spread of weeds Increased nutrients	Potential threat to endemic species[8] Reduction in short alpine herbfield and snowbank feldmark communities Increase in weeds and feral animals
Trend	Increases in grazing numbers and damage, particularly in drought years[1]	Eight-fold increase since 1970s[11]	Mild to dramatic changes to climate and snow cover predicted[12]
Management Response	Initially ban on burning off and restrictions on grazing[4] Grazing banned outright in 1944 although not totally effective for at least a decade[4] Active revegetation program as part of soil conservation[13]	Hardened/raised walkways and revegetation[14] Minimum impact codes for bushwalking and camping[15] Restriction on camping in sensitive areas[15] Potential limit in tourism numbers[16]	Reduction in greenhouse gas production[17] Control of weeds[18]
Effect	Recovery of some communities and species Continuing problem of soil erosion and weeds[19]	Reduction in damage per person, but still impacts[18] Carrying capacity of walkways regularly exceeded[2]	Limited unless effective reduction in greenhouse gas production

[1] Costin 1954; Good 1992a. [2] Clark 1992; Good 1992a. [3] Whetton 1998. [4] Costin 1954; Costin 1958; Mallen-Cooper 1990; Good 1992a. [5] NSW NPWS 1988; Good 1992a; Mackay and Nixon 1995. [6] Whetton 1998. [7] Barnes *et al.* 1987; Teramura and Sullivan 1994; Good 1998; Kickert *et al.* 1999. [8] Good 1998; Pickering 1998; Pickering and Armstrong 2000; [9] Costin 1954; Durham 1956; Taylor 1958b; Costin 1958; Costin *et al.* 1959; Costin *et al.* 1960; Wimbush and Costin 1979; Good 1992a; Costin *et al.* 2000. [10] Durham 1956; Edwards 1977; Keane *et al.* 1979; Mallen-Cooper 1990; Good 1992a; Mackay and Nixon; 1995; S.W. Johnston *pers comm.* 2000; Johnston and Pickering; *unpubl. data.* [11] Good 1992a; Mackay and Nixon 1995; S. Johnston *unpubl. data.* [12] Whetton 1998. [13] Taylor 1958a; Taylor 1958b; Clothier and Condon 1968; Costin and Polach 1971; Good 1992a. [14] NSW NPWS 1988; NSW NPWS 1998; Parr-Smith and Polly 1998. [15] AALC 1993a; AALC 1993b. [16] Worboys 1997. [17] WWF 1996; UN 1997; IPCC 1997. [18] Buckley *et al.* 2000; Pickering and Armstrong 2000; Johnston and Pickering *unpubl. data.* [19] Johnston 1995; S.W. Johnston *pers. comm.* 1999.

Johnston 1997; Parr-Smith and Polley 1998).

Although there are no formal camp sites in the alpine zone, informal areas at popular sites often suffer from severe localised trampling, nutrient addition to soil and water from human waste, fire scars, root damage from digging and collection of firewood from the few woody species (AALC 1993a; Buckley *et al.* 2000). Open fires and camping in the catchments of the glacial lakes have been proscribed in an effort to limit tourism impacts (AALC 1993a, b). The provision of 'portaloos' within the alpine area in summer and the rotating composting toilets at Charlotte Pass are likely to reduce human waste in the alpine area, although they have their own impacts and are expensive management options (AALC 2000).

Due to their confined nature, tourism impacts appear to be much more controllable than those of grazing. In summer, people tend to stay on the designated tracks and trails and can, to a large extent, be effectively guided and directed by management tools such as informative signs, raised walkways, hardened tracks and the provision of toilets (NSW NPWS 1988). The major problem is increased usage. As park authorities work towards stabilising and hardening tracks and implementing other management strategies to direct people away from sensitive areas, problems will keep redeveloping as visitor numbers increase, expanding the areas of damage. The economic costs of these methods are high, although partly offset by revenue from the entrance fee to the park (currently A$15 and A$80 per car for a daily and annual pass respectively). As the limit to the effectiveness and desirability of the hardening strategy approaches, restrictions on numbers or even closure of some areas may well be required, particularly at peak times.

Climate change

Global warming is likely to be a major threat to the alpine environment with widespread effects on the ecology of the system (Green 1998; Pickering 1998; Pickering and Armstrong 2000). Predicted changes in temperature, precipitation and snow cover (Whetton 1998) are likely to alter the distribution of native and introduced plants and animals, the hydrology of the system and soil processes (Green 1998; Good 1998; Pickering 1998; Pickering and Armstrong 2000). The direct and indirect effects of these changes on the flora are difficult to predict but are likely to involve reductions in the distribution of certain plant species and communities, particularly the snowbank feldmark and short alpine herbfield communities that are associated with late snowbanks (Pickering 1998; Pickering and Armstrong 2000).

Climate change may be a greater threat to the alpine zone than either grazing or tourism. However, the impacts of grazing and tourism have been, or can be managed by altering human activities within the park; the same approach will not work for climate change. The threat from climate change is global in nature, with the issue being human activities at a truly global scale. Therefore part of the direct management response by park agencies should be the lobbying of organisations responsible for the production and/or control of greenhouse gases, including the Federal Government.

The clear legislative obligation of NSW National Parks and Wildlife Service and other conservation agencies to maintain the natural values of the environment may require them, more and more, to assume an advocate's role for the natural environment. This type of management approach, although vital for preserving conservation reserves, is likely to attract criticism from groups who see the responsibility of the parks services as limited to issues that can be managed within park boundaries.

There are two local programs that parks agencies can undertake to assist in dealing with the impacts of climate change indirectly. The first is a watching brief. The Australian Alps national parks including Kosciuszko National Park should join international monitoring programs such as GLORIA (Global Observation Research Initiative in Alpine Environments) that examine the impacts of climate change on natural systems. Monitoring would allow early detection of critical changes in the Australian alpine flora and fauna. Documenting changes in both the climate and the biota could highlight the impact of

our activities on this fragile ecosystem, possibly adding support to moves to limit emissions.

The second program is the control of alien plants and animals. Although there are existing control programs, the problem is likely to amplify as climate change increases the abundance and diversity of weeds and feral animals in the alpine zone (Green 1998; Pickering 1998; Pickering and Armstrong 2000). It is also possible that tourism and climate change will have synergistic effects on the distribution of weeds in the alpine area further enhancing the problem (Buckley *et al.* 2000).

Conclusions

There have been, and continue to be, long-term negative effects of human activities on the Australian alpine vegetation despite expensive and committed management by conservation groups and other organisations. Grazing and associated activities have caused extensive damage to the vegetation and soil that still requires rehabilitation. Tourism, although with more localised effects, is causing damage, and has elicited expensive management responses that have their own environmental and aesthetic impacts on the region. Climate change is likely to have widespread, cascading ecological effects that are not amenable to a local management response. Currently the most effective method of limiting the impact of climate change would be to reduce greenhouse gas production, something that has been notable for its lack of success at a national level.

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Ant Behaviour Part 2

This note reports the apparently unusual and aggressive behaviour of a single Sugar Ant *Camponotus* sp. as observed at Ridge Park, Sugarloaf Reservoir, Christmas Hills, Victoria. The behaviour of this Sugar Ant contrasts with the report on Sugar Ants in the August 1999 issue of *The Victorian Naturalist* (Grey 1999) where they exhibited submissive behaviour in the presence of Meat Ants *Iridomyrmex purpureus*.

At 11 a.m. on 19 September 1999, a single Sugar Ant, subsequently identified as *Camponotus 'consobrinus'** (sub-family Formicinae) was observed at the entrance to the nest of a small, black ant, subsequently identified as *Anonychomyrma 'itinerans'* (sub-family Dolichoderinae). Identifications were made using keys from Andersen 1991, Greenslade 1979 and Shattuck 1999. The Sugar Ant repeatedly approached the nest entrance where it attacked (and was in turn attacked by) the small ants as they left, and returned to, the nest. This activity was observed for about 15 minutes and during this time one of the *A. 'itinerans'* was killed and another injured. Each bout, and there were quite a number, was short – a matter of seconds. The Sugar Ant used its mandibles to hold the small black ant while bending its abdomen (gaster) to bring the formic acid spray into action. This spray, directed through a conical opening (the acidopore) at the rear of the gaster, is used for defence and communication (Shattuck 1999). It was interesting to note the Sugar Ant ignored other species of ants, one a Ponerine species and the other a very small, brown ant (not identified), even though they were within the area where the attacks took place and close to the Sugar Ant.

In Andersen (1987), ants were grouped into seven ecological categories. *Anonychomyrma 'itinerans'* is a member of the dominant species group (Category 1). Category 1 ants are characterised as abundant, highly active and aggressive. On the other hand, the Sugar Ant *C. 'consobrinus'* belongs in Category 2 – subordinate species exhibiting submissive behaviour. Thus the aggressive behaviour of *C. 'consobrinus'* in this observation appears uncharacteristic.

* Inverted commas indicate a species group. A group is a complex of species closely allied to, and including, the named species (Andersen 1990).

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Vale

Ilma Dunn

We were deeply saddened to learn of the recent death of Ilma Dunn. Ilma was a long time member of the Field Naturalists Club of Victoria as well as an ardent supporter of the FUNGIMAP scheme and a talented photographer. A tribute to Ilma will appear in a later issue.

A Guide to Squid, Cuttlefish and Octopuses of Australasia

Mark Norman and Amanda Reid

Publisher: *CSIRO Publishing and The Gould League of Australia. 2000. 96 pp. RRP $32.95.*

All beach-goers are familiar with 'cuttlebones' washed up on the strand, with occasional views of octopus in tidal pools and with calamari rings to finish off the day. But to most, knowledge goes little further as to the actual identity of these cephalopods or where and how they live, feed, and reproduce or their behaviour and relationship to other marine fauna.

The Australasian cephalopod fauna has been the subject of much research in recent years, as we have in our region perhaps as great a number of species of squids, cuttlefish and octopuses as anywhere in the world. Lu and Phillips (1985) catalogue over 220 nominal species but the more recent research, as outlined in *The Southern Synthesis* (Beasley *et al.* 1998), would put this number closer to 180 actual species (squid, 80; cuttlefish and allies, 50; octopus, 50). However there has been little in the way of field guides for their identification. *The Southern Synthesis* (Chaps 11-13) deals in detail with the anatomy, morphology and physiology of the Class Cephalopoda and the subclasses Nautiloidea (nautilus) and Coleoidea (cuttlefish, squids, octopuses). In the latter chapter keys to the various families are given (with line drawings of representative taxa) but lower taxonomic identifications are not made. In southern Australia we are a bit more fortunate in that Zeigler and Norris (1989) give keys and brief descriptions and some colour photos of our cephalopod fauna, and Edgar (1998) also has a small section on this fauna – but neither of these two books is complete nor easily used in the field.

Now, in this new publication by Norman and Reid, we have a very readable guide to the specific identity of at least some of the cephalopod fauna of the wider Australasian region. The fauna mentioned includes species from all parts of the Australian coastline with a number which occur only in the islands to our north. Some of the taxa have very extensive ranges, occurring throughout the western Pacific region, whilst others are quite restricted, e.g. The Capricorn octopus, known only from a single island group in the Great Barrier Reef. Introductory chapters deal very briefly with the evolution of cephalopods in geologic time, cephalopods today and the means of identifying the various groups of cephalopods. The largest section deals with sixty-three of the more common species of squids, cuttlefish and octopuses found in mainly shallower waters. Taxa described range from the huge Giant Squid (up to 2 metres mantle length and 18 metres overall) to species less than 2 cm overall length, and from those living in intertidal pools to the soft, gelatinous octopuses living at depths of several kilometers. One page is usually devoted to each species which is described with a half-page colour photo, a distribution map and a brief discussion of some of the more important points of the animal and something of the biology where known. A final section figures the most common beach-stranded sepions ('cuttlebones') although I feel that the rosy, bronze and bluish hues of these figures, which may be true of live-taken sepions, are quite strange for the normal white objects found on the beach. There is a short reading guide, a glossary and an index to complete the book. This book could be quite easily carried and used in the field but would almost certainly not stand immersion.

There is still a great deal to be found out about these animals – just two quotes from *The Southern Synthesis* – 'Life histories of the overwhelming majority of cephalopods are still unknown...' (p. 470) and '...the taxonomic importance of observing the

colour patterns, skin textures and body postures of live animals' (p. 476). This is where the amateur beachgoer or diver can assist. Interesting, and previously unknown, behaviour of these animals can be gained if we take the opportunity of a chance encounter to simply observe e.g. Vafiadis (1998) on *Octopus maorum*. I feel a short section, with this in mind, on observing (photography, video-recording), collecting and preserving specimens would have been useful.

The photographers are to be congratulated as the photos used are quite exquisite (I liked the Striped Pyjama Squid) and, taking into account the colour changes that the Coeloidea are capable of with their chromatophore systems, should enable confident identification of the species dealt with.

I would recommend this book as a very useful guide for all marine-goers.

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Flora of Australia Volume 48
Ferns, Gymnosperms and Allied Groups

Publisher: *(ABRS)/CSIRO, 1998. 766 pp. 96 colour photographs, numerous black and white drawings, distribution maps. ISBN 0 643 05972 5 (soft cover). RRP $99.95*
Available from CSIRO Publishing, PO Box 1139, Collingwood, Victoria 3066.

This wonderful volume of *Flora of Australia* caters for all those interested in our Australian non-flowering vascular plants. It is divided into two main sections, the ferns and fern allies and the gymnosperms. In each instance, a brief review of the taxonomic history of each group is provided giving the reader a quick, albeit rudimentary, understanding of previous taxonomic research. Similarly, the reader is given an overview of the morphology, biology and ecology of the two broad groups. This is ideal for those in the early stages of their studies although they must come to grips with terminology. To assist with this, a glossary of specialised and frequently used terms for the ferns, conifers and their allies is included at the back of the volume. It is not exhaustive but this is acknowledged and the reader is advised to use it in conjunction with the glossary in *Flora of Australia* Volume 1.

I have tested the key to the families of ferns and fern allies in Australia and found it simple and easy to use, making it ideal for the student and amateur and highly desired by the professional botanist! Each family has its own key to genera and each genus, similarly, has its own key to species. Although I have not tested all of these, they are designed in the same manner as the key to families and appear straightforward. Indeed, the ones I have tried posed no problems. Descriptions are

brief and to the point, as they should be, photographs and drawings generally are of high quality, showing the intricate detail and quiet beauty of selected specimens. The proliferous buds in the distal axils of *Callipteris prolifera* (Figure 88 in the Volume) and the aerial shot of *Platycerium superbum* (Figure 150 in the Volume) are particularly captivating. Short notes on habitat and distribution are presented and information on type collections, chromosome numbers and published illustrations provided, supplemented by significant references and synonymy. This occurs for the gymnosperms as well.

No single key to the families of gymnosperms was provided, instead, each division has its own key to families, then families to genera etc. Several keys to families are provided for the Pinophyta: based on female specimens, male specimens and on vegetative characters. Again, photographs and drawings are of high quality and show the attention paid to detail by the photographers and artists. In both the gymnosperms and the fern and fern allies many of the photographs and diagrams are of reproductive structures, accentuating their importance as identification tools.

The chapters dealing with the fossil records of the ferns and fern allies and the gymnosperms are an important inclusion and help piece together the scattered information available, providing a holistic view of the changes that occurred over time with respect to these plant groups. The importance of continued comparative investigation of extant and fossil flora is highlighted by the mention that the discovery of Wollemi pine *Wollemia* supported the hypothesis that the Araucariaceae may have included an additional genus in the past, although, *Wollemia* has not been confirmed as a fossil. There still is much to be understood about the fossil record of our Australian non-flowering plants. Why, it is asked, did *Dacrycarpus* become extinct when apparently more susceptible genera survived? This is an important question as Australia is a large land mass and has, and presumably had, a wide variety of habitats. Why did *Cyathea* fail to recover from the last glacial when it has survived more extensive glaciation? Is there a factor restricting its expansion? If so, what?

The collation of the distribution maps for each species is particularly useful. In the first instance, it allows a rapid visualisation of the Australian biogeography of each species but, also, allows easy comparison between species. The instant recognition of isolated occurrences of many species highlights their vulnerability and the importance of their conservation/preservation.

An appendix presents new taxa, combinations, lectotypifications, epitypifications and neotypifications. There are quite a number of these accentuating the enormous amount of work done by the authors. One of the amazing points to note is that even large new species still are being described. Obviously there is a lot more work needed!

This volume of the *Flora of Australia* is comprehensive, authoritative, and written in easily understood English. The numerous black and white line drawings are an excellent aid to the text and, conveniently, are usually adjacent to the text or on the next page. The colour photographs were divided into three groups, which were dispersed throughout the volume, serving to break the monotony of black and white. While the photographs, therefore, were not near to the relevant text and some flipping of pages back and forth was necessary, it is understandable that this should occur, especially when considering convenience for putting the publication together and associated costs. There are a number of 'typos' scattered throughout the text, including incorrectly spelt words and omissions but this is a minor fault and the reader should not let this detract from the otherwise superb presentation of the volume. I highly recommend that anyone even remotely interested in Australia's ferns, fern allies and gymnosperms save their pennies, fill their piggy-banks and buy a copy of this volume of *Flora of Australia*!

Maria Gibson
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Compendium of FUNGIMAP Target Species
Version 1.0 [CD-ROM]

Publisher: *FUNGIMAP, Melbourne, Australia. RRP $15.00*

This outstanding first FUNGIMAP CD-ROM provides the user with detailed information on the 100 FUNGIMAP Target species in the form of written descriptions, numerous photos and illustrative material as well as the distribution maps created from the records sent in by volunteers across Australia. The CD also includes general information on FUNGIMAP, a glossary of mycological terms, and basic information on the structure of fungi. For those interested, further mycological information may be gained from the list of reference books and fungi web sites.

The opening screen makes it so easy to get started – just click on the topic *How to use this CD-ROM* and all is revealed. The icons are explained and navigation through the CD is clearly laid out. The opening statement was particularly reassuring: 'Explore the CD-ROM in any manner you like. You can't do it any harm and you can always return to the start by clicking this icon [HOME]'. *Troubleshooting* is also very helpful, especially with older machines and earlier versions of Windows where sometimes the whole screen is not visible, or 'the image is awful'. Answers are given with easily followed solutions. However, the CD-ROM needs a computer with a colour resolution of 800x600 (and higher) pixels, and is, unfortunately, only available for PC's not Mac's. The first screen is clearly set out with a list of topics on the right and on the left, a diagrammatic 'mushroom cap' divided into segments that when highlighted and clicked lead to the descriptions of the 100 FUNGIMAP Target species.

Everything that you need to know about participating in FUNGIMAP is included in the headings under *Fungimap*. In *Fungi Features* the stages of 'why a mushroom is mushroom-shaped' is amusing – first there is a sketch of a gill, a pore and a tooth, then clicking on the next 'principles' you get a collection of gills/pores/teeth, then 'a cover to keep off the rain' etc. This is especially useful for those of us who are new to the subject. Additional documents can also be accessed that include information for beginners, record sheets etc., and FUNGIMAP Newsletters 1-12.

In the next topic, *Fungi Skills*, microscopic images of some fungi spores have been included which further adds to the interest and study of the subject. The *Resources* topic shows the paucity of purely Australian fungi books, and indicates how necessary this CD-ROM is. Throughout the topics there are direct access routes to fungi web sites other than the FUNGIMAP site. This feature is very useful.

Back to the fun part of the opening screen – finding out about the 100 FUNGIMAP Target species. Access to each species can be done in a number of ways as indicated on the 'mushroom cap', which is divided into 8 segments and an inner circle. As the cursor moves over any of the sections, sample illustrations and text appears in boxes, which give more information about that segment. *All targets,* in the centre of the 'cap', takes you directly to the descriptions of the species starting at A – *Agaricus xanthodermus* Yellow Stainer as 1/100 down to 100/100 *Volvariella speciosa.*

From the outer segments of the 'cap', you can select whether you want to look at gilled fungi, those with pores or teeth, or any of the other types. All these, when activated, take the reader to a second screen with tagged files and thumbnail illustrations of each species. Clicking on any of the species illustrated will take you to its description. On the other hand, you can go to the Taxonomy segment that lists the species in their order, family, genus and species, and by clicking on any of the species here you can also go directly to the description. There is also another way to access the species, which I particularly liked – by colour. At the second screen the

thumbnails are arranged in colour. I also found helpful those fungi listed by habitat, i.e. the *desert fungi,* and think it would also be useful if other species could be grouped according to habitat, or substrate.

The first screen of the description gives the name, etymology, taxonomy and common name, if there is one. Most of the screen is taken up with an illustration of the species, with arrows indicating the relevant macroscopic features that are characteristic of the fungus. This is an excellent feature and backed up with the more detailed description (accessed by the 'page' icon on the screen), and further photos (accessed by the 'camera' icon) enables a positive recognition of the species. The number of additional photos of the species is another commendable feature. They show the species in a variety of stages and aspects, thus giving the reader a 'concept' of the species, which is very important since fungi are so variable in many cases. The photos are excellent, and the wonderful thing is that FUNGIMAP volunteers have contributed all (over 700) free of charge. Unfortunately not all the species have further written descriptions, or a variety of other photos, thus making it difficult to identify these species, especially for beginners.

The map icon shows the distribution of the fungus. It is particularly gratifying that FUNGIMAP volunteers' records have very greatly increased the information on the distribution of most species. The red FUNGIMAP squares dominate almost every map (the blue ones indicate herbarium specimens, and the green, literary records). Victoria and Tasmania are seen to have a lot of records, but this is probably the distribution of recorders rather than a dearth of FUNGIMAP targets elsewhere.

Other information included with some species is a spore print, and any 'look alike' fungi. One feature I particularly liked was that when *Cyttaria gunnii* was said to grow on Myrtle Beech, by clicking on the camera icon near this information, an image of the Myrtle Beech was shown, similarly with *Banksiamyces macrocarpa* on *Banksia spinulosa.*

This is just the first version (see *How to use this CD-ROM – the 2nd edition*) and a later edition will fix up the lack of descriptions and photos as well as adding further features and an enlarged target species list. I shall look forward to that.

Ian Bell is to be congratulated on putting together such an elegant program – easy to use and tremendous fun. It will be especially useful for those just starting with FUNGIMAP; in fact, fungi in general, since there is information on many genera.

The RRP of $15.00 makes this CD-ROM an extremely good buy.

Pat Grey
8 Woona Court,
Yallambie,
Victoria 3085.

CD available from FUNGIMAP Royal Botanic Gardens Melbourne, Birdwood Avenue, South Yarra, Victoria 3141. Cost $15.00 + $3.00 (GST + postage and handling) anywhere in Australia. Cheques made out to: Field Naturalists Club of Victoria

100 Years Ago

WHERE THE BIRDS GO TO —

In a recent issue of the *Daily Mail* (London) some account was given of a sale of bird skins in that city. One firm sold no less than 2,151 female Birds of Paradise, while another had 847 and a third 531! These were sold in lots of 50 or 60 at from 16s. to 24s. per skin. One of the firms had 1,181 Impeyan Pheasants, together with large quantities of Osprey feathers, skins of parrots, jays, owls, crested pigeons, and other birds. A line of 1,000 lately deceased "Pretty Pollies" went off at $1^1/_4$ d. each!

From *The Victorian Naturalist* Vol. **XVIII**, 1901.

Stefanie Rennick
27 March 1918 – 3 January 2001
Environmentalist and Naturalist

Stefanie Rennick joined the Field Naturalists Club of Victoria 18 years ago, in 1983. About this time she also became a prominent environmentalist on the Mornington Peninsula. She joined the newly formed Southern Peninsula Tree Preservation Society and put to work her visions for the protection of biodiversity in the region. She was already a long time member of the Melbourne Women's Walking Club and also had an increasing interest in native plants. When there was a plan to subdivide part of Greens Bush she campaigned strongly for the whole area to be put into the Mornington Peninsula National Park. Finally, when this goal was realised, and when walking tracks were being constructed she had visions for a field guide for the whole Peninsula. A book committee was set up and a grant obtained. Stefanie worked tirelessly at this with assistance from Ilma Dunn, who supplied most of the photos. The book, 'The Mornington Peninsula: A field guide to the flora, fauna and walking tracks' (1990), was a great success, raising over $40,000 in book sales which she requested go to Trust for Nature to be used only for conservation on the Mornington Peninsula.

One campaign Stefanie fought strongly for was the relocation of the Main Ridge Equestrian Centre from Council-owned land adjacent to the Mornington Peninsula National Park. *Phytophthora* had been found in the area near a stream that runs into the Park, causing a serious threat to the flora of the Park. Stefanie fought Council bureaucracy for years in this ongoing saga and it is unfortunate she did not live to see the matter resolved. On a brighter note Stefanie had been engaged in a long-running dispute with the Shire over slashing roadside verges in late spring when many late flowering native species had not set seed. Because of her tenacious spirit, Council has changed its attitude and has identified many roadside verges for special protection.

Stefanie was also a member of the Southern Peninsula Indigenous Fauna and Flora Association and always had lots to say on local matters. At meetings she would nearly always bring along a bunch of environmental weeds to educate members, and spoke strongly for weed removal. All those she inspired are determined to keep fighting for the things she believed in and her vision for the

Peninsula. A granite tor with a bronze plaque has been erected in her honour on a section of the Two Bays Track. It reads

> In honour of
> Stefanie Rennick
> Teacher, Naturalist, Environmentalist
> and Bushwalker
> whose vision saw the establishment of
> The Two Bays Walking Track,
> and who has fought tirelessly for the
> Preservation of Mornington Peninsula's
> Biodiversity.
> A woman for all seasons.

Stefanie's environmental activities also extended to suburbia, where she used her teaching skills to introduce the students at Ormond East Primary School to indigenous plants. Together they built and looked after a native garden at Joyce's Park and thus she passed her knowledge and environmental ideas on to a new generation.

She was also involved and participated in activities with the Victorian National Parks Association, Native Corridor Research Group, and The Australian Plants Society (where she was made a life member). Somehow she also found time to contribute to *The Victorian Naturalist*!

Tom Sault
51 Russell Street,
Tootgarook, Victoria 3941.

Stefanie's photo supplied by her family.

Lyle Courtney, OAM

Congratulations to Lyle Courtney, a long-time member of the Maryborough Field Naturalists Club, who was awarded the Medal of the Order of Australia in the General Division on Australia Day, 26 January 2001. Lyle's award was 'for service to the community through the collection and supply of Red-back Spider specimens for the production of antivenoms by the Commonwealth Serum Laboratories'.

Inspired by an appeal from the late Crosbie Morrison, Lyle began collecting Red-backs in 1955 and over a period of more than 43 years supplied over 50,000 spiders to CSL. The vast majority of the spiders came from within a 50-mile radius of Maryborough, and, in true field naturalist style, Lyle has a record of every spider sent over the years to CSL.

The individual spiders required by CSL had to be large, so of course when Lyle was collecting he would see ten times more Red-backs than he captured and feels he can justifiably claim 'to have seen more Red-back Spiders than anyone else in the history of the human race'.

Lyle Courtney is probably more well-known to many members of the FNCV for his untiring conservation efforts in the last remaining remnants of his local Box-Ironbark forest.

Congratulations Lyle from all your FNCV colleagues.

The Editors

The Field Naturalists Club of Victoria Inc.

Reg No A0033611X

Established 1880

In which is incorporated the Microscopical Society of Victoria

OBJECTIVES: ***To stimulate interest in natural history and to preserve and protect Australian flora and fauna.***

Membership is open to any person interested in natural history and includes beginners as well as experienced naturalists.

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Members receive *The Victorian Naturalist* and the monthly *Field Nat News* free. The Club organises several monthly meetings (free to all) and excursions (transport costs may be charged). Field work, including botany, mammal and invertebrate surveys, is being done at a number of locations in Victoria, and all members are encouraged to participate.

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Published by The Field Naturalists Club of Victoria *since 1884*

Vale Ilma Dunn

1911 – 2001

Photographer and Naturalist

Around 1960 Ilma joined the Native Plants Preservation Society and, in 1963, the Bird Observers Club. She joined the Field Naturalists Club of Victoria in 1972. From that time she was an active participant in the Club, especially the Botany Group, leading excursions and giving talks, including a memorable slide show of high country plants set to music. Ilma enjoyed attending Club and Botany Group meetings, and was a regular until prevented by frailty in recent years. She often brought along some interesting recent find for the table of exhibits, and also helped to prepare displays for open days. Her husband, David Dunn, also attended many Club activities, and was FNCV Treasurer from 1980 to 1984 (see *The Victorian Naturalist* 114: 259).

Already a keen photographer before joining the FNCV, her knowledge of natural history and skill in wildflower photography developed rapidly, her pictures being much admired for their artistic quality as well as their technical excellence. Ilma's favourite subjects were orchids and fungi, and she also photographed many wildflowers. She had a wide knowledge of plants and fungi, was interested in growing native and exotic orchids, and was also interested in the details of natural history, such as observing insect pollinators of orchids. Ilma sent in one of the very first batches of records to the Fungimap scheme in 1995, and continued to support the scheme by providing records and photos.

A number of Ilma's photographs appear in two recently published books. One is 'The Mornington Peninsula – a Field Guide to the Flora, Fauna and Walking Tracks' of which she was also a joint author with the late Stephanie Rennick. More recently, the book 'Wildflowers of Victoria', by Margaret Corrick and Bruce Fuhrer, contains further examples of her work.

Ilma and her husband David were enthusiastic supporters of the 'Photoflora' competitions and exhibitions organised by the Native Plants Preservation Society from 1963 to 1980. Ilma contributed both as a committee member, slide contributor and judge. She also played a major part in organising the subsequent 'Mini-Photoflora' series of audiovisuals which were made available to the public for borrowing and display.

Ilma was actively involved in the many projects of the Society to save and protect small areas of valuable native vegetation in danger of being lost to development. Through this activity she became a foundation member of the group whose work led to the setting aside of the Barak Willem Flora Reserve in South Belgrave with its wealth of botanical interest.

Ilma was very generous in allowing others to use her photos in talks and publications. Her photos appeared in the Viridans CD-ROM Wild Plants of Victoria, and are also represented in the NRE Flora Information System. A superb photo of the blue toadstool *Entoloma virescens*, taken by Ilma in New Zealand, featured on the front cover of a recent issue of *The Victorian Naturalist*, Volume 118 (2). Her collection of more than 5 000 photographs is now housed at the Royal Botanic Gardens Melbourne. Ilma and David were close friends of Jim and Mavis Willis and Ilma also took some photographs for Jim on excursions in his later years.

In her last years, when no longer able to attend meetings or visit the bush, Ilma continued to enjoy her nature photography using the many fascinating plants, flowers and insects in her own garden. Serious ill-health in early 2001 curtailed her activity but she reached her 90th birthday in May, celebrating the occasion quietly with friends and relatives. She died peacefully in her sleep on the night of her birthday.

Ilma will be remembered fondly by her many friends in the FNCV for her gentle and inquisitive nature. She was always good company on excursions, and ever willing to share her knowledge of and enthusiasm for plants and fungi, and assist others with photographic techniques.

This tribute has been compiled from information kindly supplied by Geoff and Ruth Christensen, John Eichler, Paul Gullan, Tom May and Hilary Weatherhead.

The

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F.N.C.V.

Editor: Merilyn Grey
Assistant Editors: Alistair Evans and Anne Morton

Research Report

Long Distance Transport of Arsenic by Migrating Bogong Moths from Agricultural Lowlands to Mountain Ecosystems, *by Ken Green, Linda Broome, Dean Heinze and Stuart Johnston* 112

Contributions

A Review of Insect-induced Galls and Mistletoes on Buloke *Allocasuarina luehmannii* in the Victorian Wimmera, *by Matthew F. Wright and Diana R. Burgess* 117

Opportunistic Vertebrate Predation by the Squirrel Glider *Petaurus norfolcensis, by Greg J. Holland* 123

Human and Natural Impacts on the Upper Yarra Region with Reference to the Yellingbo Nature Conservation Reserve: a Review, *by Sabine Kasel* 127

Book Reviews

Nature Photography, *by Ken Griffiths, reviewed by Anne Morton* 142

Wildflowers of Victoria, *by Margaret G. Corrick and Bruce A. Fuhrer, reviewed by Bernadette Sinclair* 143

Honours

David Ashton, OAM 140
W. Rodger Elliot, AM 141

Tribute

Vale Ilma Dunn 110

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Cover: The Squirrel Glider *Petaurus norfolcensis* has been found to occasionally feed on vertebrates. Photo by John Seebeck. See article on page 123.

Our web page: http://calcite.apana.org.au/fncv/vicnat.html
email: fncv@vicnet.net.au

Long Distance Transport of Arsenic by Migrating Bogong Moths from Agricultural Lowlands to Mountain Ecosystems

Ken Green[1], Linda Broome[2], Dean Heinze[3] and Stuart Johnston[4]

Abstract

Bogong Moths *Agrotis infusa* (Lepidoptera: Noctuidae) migrate in spring from the inland plains of eastern Australia to aestivate up to 1000 km away in rock crevices in tors and periglacial block-streams in the Snowy Mountains and Victorian Alps. In spring/summer 2000/01, heavy rains washed debris from caves in the Snowy Mountains, killing adjoining grass. Arsenic was detected in soils from the caves and soil and grass from outwash areas, but not in soils and grass from adjacent unaffected areas. Faeces from mammalian predators of moths contained more arsenic than faeces from a herbivore from the same region. Arsenic levels were higher in moths from caves in the Snowy Mountains where vegetation was killed than in moths from the ACT or Victoria. The results indicate long distance transport of sublethal quantities of arsenic which are then concentrated to damaging levels by the millions of moths at aestivation sites. (*The Victorian Naturalist* **118** (4), 2001, 112-116.)

Introduction

The larvae of Bogong Moths *Agrotis infusa* (Noctuidae) are found from autumn to spring in eastern Australia from the Darling Downs in Queensland, south to the north-western plains of Victoria (Fig. 1). These areas have historically been used for grazing and cropping, and the Bogong Moth cutworm larvae are sometimes considered an agricultural pest (Common 1954). The larvae feed on annuals, but in the absence of their food plants over summer the moths migrate to the Australian Alps where they fast while aestivating gregariously in rock crevices and caves (Common 1954). Historically, Bogong Moths formed an important part of the summer diet of Aboriginal people from around the Australian Alps (Flood 1980). Today they still form an important part of the diets of many vertebrate species, including the endangered Mountain Pygmy-possum *Burramys parvus*, the most reliant of the native mammals on Bogong Moths (Mansergh and Broome 1994).

Heavy rains in November 2000 washed accumulated debris of dead moths out of many aestivation sites. In January 2001 complete mortality of grass *Poa fawcettiae* in the outwash zone at one site prompted an investigation of possible chemical contamination in the moths, the affected soils and vegetation.

Methods

In order to examine soil chemical properties in detail, soil samples were collected (approximately 0-10 cm depth) from up to five separate areas within each site and samples were then pooled. Samples were collected from within caves used as aestivation sites by Bogong Moths, in the area outside the cave over which water and debris from the cave had drained, and as close as possible to this but outside of the drainage line from the cave. Soil exchangeable cations were determined using an ammonium acetate extraction (Lambert 1978) and analysed on a Varian Flame Atomic Absorption Spectrophotometer. Statistical analysis of arsenic levels was undertaken using two-way ANOVA.

From preliminary findings it was established that arsenic occurred in higher concentration in affected soils, and therefore, subsequent analysis concentrated on this one element.

Bogong Moths were collected live by hand at aestivation sites or by ultra violet moth lights at Mt. Gingera (ACT), South Ramshead (Snowy Mountains NSW) and from Mt. Buller and Mt. Buffalo (Victoria) (Fig. 1). Sample size varied from 50-120 moths depending upon availability, and

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[2] National Parks and Wildlife Service, Threatened Species Unit, PO Box 2115, Queanbeyan, NSW 2620.
[3] La Trobe University, PO Box 821, Wodonga, Victoria 3689.
[4] Johnston Environmental Consulting Pty Ltd, 5 Nightingale Lane, Berridale, NSW 2628.

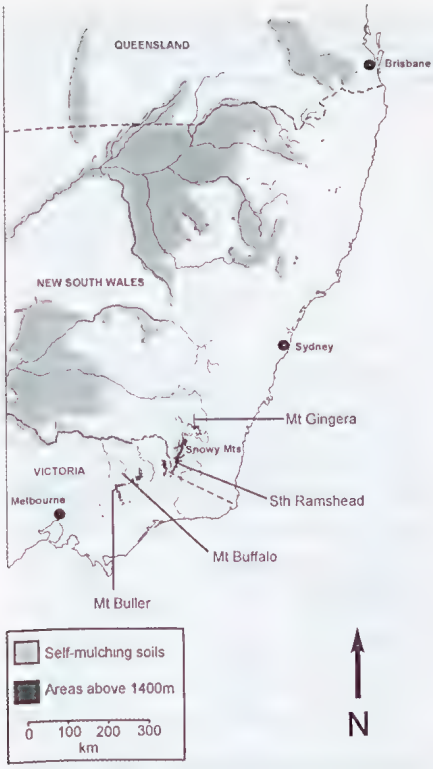

Fig. 1. Map of south eastern Australia showing areas above 1400 m altitude, including the mountain aestivation sites sampled in the present study, and the chief areas of self-mulching soils that appear to be the most important breeding grounds of Bogong Moths (after Common 1954).

samples were pooled and frozen as soon as possible after capture. Analysis was of a subsample of approximately 50 moths (adjusted to give approximately equal mass) from each location. Analysis of arsenic levels in Bogong Moths was conducted using a nitric acid digest (modified from Rayment and Higginson 1992) with arsenic determination on a Varian Vista ICP-MS (Inductively Coupled Plasma - Mass Spectrophotometer).

Samples of grass were collected from three to four sites of approximately 400 cm^2 within the area outside the cave over which water from the cave drained (dead grass) and from adjacent to this, outside of the cave drainage but still close to the rocks (live grass). Grass samples were pooled, sub-sampled and then prepared using a wet acid digestion method using hydrochloric acid (Lambert 1978, Rayment and Higginson 1992) and analysed on a Varian Flame Atomic Absorption Spectrophotometer.

Table 1. Elemental arsenic content of Bogong Moths *Agrotis infusa* compared to a known sample of 0.0000 $\mu g.kg^{-1}$ arsenic (for use with samples at low concentrations).

Location	Elemental arsenic ($\mu g.kg^{-1}$)
Control (known sample)	0.103
Mt. Gingera (ACT)	0.101
South Ramshead (NSW)	2.296
Mt. Buffalo (Vic)	0.186
Mt. Buller (Vic)	0.333

Sub-sampling of stored faeces of Mountain Pygmy-possums was conducted following the discovery of arsenic in the mountain system. Faecal samples had been collected annually for dietary studies and stored frozen. Individual samples were sub-sampled so as to retain information on diet, and all samples for one area were then pooled. Three other mammal species were also tested. These were trapped at Smiggin Holes, 3.5 km from the nearest Bogong Moth aestivation site. These had differing diets ranging from insectivorous (Dusky Antechinus *Antechinus swainsonii*), omnivorous with the major food being fungus and insects (Bush Rat *Rattus fuscipes*) and one obligate herbivore (Tooarana or Broad-toothed Rat *Mastacomys fuscus*) (Green and Osborne 1994). Samples from the latter species were chosen as representative of background levels of arsenic in mountain mammals. Only *M. fuscus* is marked individually on the trapping grid, so samples could be collected from individuals over the three days of trapping. For the other two species which were not marked individually, faeces were pooled from all animals after the first night's trapping. Analysis of arsenic levels in faecal samples was undertaken using ICP-MS (Inductively Coupled Plasma - Mass Spectrometry) on a Hewlett Packard HP4500 ICP-MS using nitric acid digest (Rayment and Higginson 1992).

Table 2 Arsenic levels in soils adjacent to moth aestivation sites where live moths were sampled and for all sites combined. (Each site is pooled from up to five samples.) Mean and standard deviation.

Site	Grass state	Elemental arsenic ($mg.kg^{-1}$)
South Ramshead site 2 – in cave	n/a	15.7272
South Ramshead site 2 – outwash area	Dead	3.5551
South Ramshead site 2– undisturbed	Live	0.0000
Average of 8 sites – in cave	n/a	6.0292±8.9292
Average of 8 sites – outwash area	Dead	0.5035±1.2553
Average of 8 sites – undisturbed	Live	0.0005±0.0013
Mt. Gingera – in cave	n/a	0.1542
Mt. Gingera – outwash area	Live	0.0000
Mt. Gingera – undisturbed	Live	0.0000

Results and Discussion

The movements of arsenic from Bogong Moths to soil to grass and from moths to mammals are firmly established (Tables 1-4). There was a significant trend ($F=3.593$, $P<0.05$) of decreasing levels of arsenic in soils from caves to unaffected sites outside of drainage lines (Table 2) that mirrored the observed effect on vegetation. The analyses of unaffected soils, live grass and herbivore faeces indicated that the arsenic in the affected soil, dead grass and faeces of insectivores was not of local origin but had been introduced to the system by immigrant insects. The presence of arsenic in the most heavily preyed upon insect, the Bogong Moth (Table 1), indicates that these moths are the source of arsenic at the aestivation sites. Bogong Moths do not feed locally during aestivation (Common 1954) so it is most likely that the arsenic originated in the soils where the larvae feed (I.F.B. Common, *pers. comm.*). The distances between the larval sites inland to the aestivation sites in the mountains is up to 1000 km. This finding constitutes yet another example of long-distance transport of pollutants, but one that is unusual in that an insect is the transporting agent. Although there are few data on insects, the levels of arsenic detected in moths at the most affected site were well below levels causing mortality of moths elsewhere (Eisler 1994). Arsenic levels in moths were highest at the location where the impact of outwash from aestivation sites on vegetation was first noted at South Ramshead. Arsenic levels in caves and outwash (Table 2) reflect the differing levels found in the moths at Mount Gingera and South Ramshead (Table 1). Soils at five other sites where grass was killed had similarly elevated levels of arsenic in the cave and outwash relative to undisturbed soil. Unfortunately the phenomenon was noticed too late in the season to sample moths at those sites prior to their emigration. The compound containing the arsenic has not yet been identified, due to the shortage of moths subsequent to the main migration, but all dead grass contained levels of arsenic not found in live grass (Table 3). There was obviously uptake of arsenic from the soil by the grass although the causal connection of arsenic with grass mortality is not firmly established. The arsenic levels in soils in two caves at South Ramshead, a major aestivation site south-west of Mt. Kosciuszko, were higher, at 15.7 and 23.8 ppm, than residues generally found in farmlands in America (Yan-Chu 1994) and orchards in New South Wales (EPA 1995) but within the range of residues accumulated in orchards in America (Yan-Chu 1994).

Table 3. Elemental arsenic content in affected and unaffected grass beside moth aestivation sites at South Ramshead. (Each site is pooled from up to four samples.)

Site	Grass state	Elemental arsenic ($mg.kg^{-1}$)
Site 1		
– edge of cave	Dead	0.005
– outwash area	Dead	0.006
Site 5		
– undisturbed	Live	0.000
– outwash area	Dead	0.006
Site 6		
– outwash area	Dead	0.007

Arsenic appears to be well entrenched in the mammalian insectivore food chain,

Table 4. Elemental arsenic content (mg.kg^{-1}) of faeces of three mammal species that feed on Bogong Moths and one herbivore (*Mastacomys fuscus*) acting as a control.

Year	1994	1995	1998	2000
Burramys parvus				
Trap grid 1	0.1	0.4	0.1	<0.2
Trap grid 2	<0.5	1.6	<0.2	<0.2
Trap grid 3				<0.5
Trap grid 4	0.2	<0.1	0.3	0.3
Trap grid 5	<0.5	0.8*	0.1	<0.5
Trap grid 6	0.2	0.4	<0.5	0.3
Smiggin Holes:				
Antechinus swainsonii				0.5
Rattus fuscipes				0.6
Mastacomys fuscus				<0.1

*1994 and 1995 combined.

with only one species of small mammal tested, the herbivorous Tooarana or Broad-toothed Rat, being unaffected. The impacts of arsenic within the mountain ecosystem are unknown. The small size and the rarity of dead specimens of the endangered Mountain Pygmy-possum make it difficult to collect samples to determine the levels in tissue and to speculate as to its possible effect in suppressing the population of Mountain Pygmy-possums.

Bioaccumulation of environmental pollutants and their concentration by terrestrial organisms normally occur *in situ* in, for example, plants such as willows (*Salix* spp.) (Larison *et al.* 2000). Exceptions to this are where transport of pollutants occurs through the action of wind or water prior to uptake (Sivertsen *et al.* 1995; Kalas *et al.* 2000) with levels generally decreasing with distance from the source (Kalas *et al.* 2000). What is less frequently documented is the long-distance transport of small amounts of chemicals by individual organisms and subsequent concentration to detrimental levels. The altitudinal flow of anthropogenic nutrients such as crop fertilisers has, however, been documented for phosphorus in windblown Alfalfa Moths *Loxostage cerareolis* (Halfpenny 1994).

Polluting sources such as smelters and fossil fuel power plants are major sources of arsenic in surface soils (Yan-Chu 1994). However, Bogong Moths come from upwind of the eastern seaboard of Australia where industry is concentrated. It is possible that there are natural sources of arsenic in systems from which the larvae feed which are amplified by bioaccumulation via the Bogong Moths. However, a more likely source is agricultural. The use of arsenic in agriculture has left a legacy of broad-acre contamination of soils, mainly associated with areas of intensive agriculture and horticulture (EPA 2001). Arsenic has been used in a variety of agricultural applications: in pesticides, insecticides and in cattle and sheep dips (Azcue and Nriagu 1994). It has also been used as lead arsenate for the control of moths in fruit crops (Buchanan 1977; Yoon and Kim 1977). From the 1860s to 1940s, when DDT was introduced, arsenical compounds were the major insecticides available to agriculture (Nriagu and Azcue 1990) and remained in use in Australia until the 1950s and 1960s (EPA 2001). The major use of arsenic is still in agriculture in various forms including monosodium methylarsonate (MSMA) (Azcue and Nriagu 1994). There are five MSMA herbicide sprays currently licensed for use in agriculture in New South Wales (National Registration Authority 2001). In soils, arsenic is present as arsenate (AsO_4^{2-}), and its behaviour resembles that of phosphate (Davies and Jones 1988). For example, arsenate is absorbed by ligand exchange on hydrous iron and aluminium oxides (Davies and Jones 1988). This study shows that the soils of the Snowy Mountains have naturally low levels of exchangeable arsenic. Addition to these soils of exogenous arsenic, which is readily taken up by plants, has led to major impacts on the vegetation around the aestivation areas.

The presence of arsenic in all four years for which faeces of *B. parvus* were tested (Table 4) suggests that arsenic may be transported to the mountains annually. This suggests that there may be regular absorption of arsenic by the cutworm larvae, probably from their food plants. Small amounts of arsenic are then transported at low concentrations, by individual moths but in extremely high numbers, and concentrated where they congregate in the mountains, causing visible and extensive damage. The arsenic content of moths and soils at Mt. Gingera (Tables 1 and 2), contrasting to those at South Ramshead and in Victoria, suggests that there are different sources of these moths. It has long been suspected that Bogong Moths in different aestivation sites come from different areas and this study adds credence to that speculation. This question may be resolved by genetic studies matching adults to larvae from known agricultural areas. Collection of material for this study is currently in progress with the primary aim of the genetic study being to narrow the focus of searching for the source of the arsenic.

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International Year of Mountains 2002

The United Nations has declared 2002 as the International Year of Mountains. The aim is to celebrate and focus global attention on mountain communities and environments. A number of activities associated with mountain environments in Australia are already planned including a 'biodiversity blitz' at Kosciuszko in January (under the auspices of the Australian Institute of Alpine Studies) and a conference on rehabilitation of mountain ecosystems in November (Australian Alps Liaison Committee).

A Review of Insect-induced Galls and Mistletoes on Buloke *Allocasuarina luehmannii* in the Victorian Wimmera

Matthew F. Wright[1] and Diana R. Burgess[2,3]

Abstract
Remnants of Buloke *Allocasuarina luehmannii* on the Wimmera plains of Victoria are host to gall-inducing insects and mistletoes. The taxonomy, life cycle and morphological variability of the *Cylindrococcus* gall-formers are reviewed, together with their potential for damage and methods of control. The host range and population status of two buloke-associated mistletoe species, *Amyema linophyllum* and *Lysiana exocarpi*, are described and their effects on the buloke host are considered. The review revealed a lack of information about environmental factors that may cause gall and mistletoe populations to increase at the expense of their buloke hosts. (*The Victorian Naturalist* **118** (4), 2001, 117-122.)

Introduction

Buloke *Allocasuarina luehmannii* R.T. Baker (Casuarinaceae) is the dominant or co-dominant tree species in remnant woodlands on the Wimmera plains of Victoria (Lunt *et al.* 1998). These ecosystems were once extensive on the better-drained, fertile soils of the Wimmera (Goucher 1982; Morcom and Westbrooke 1998) and played a vital role in the ecology of indigenous flora and fauna (Connor 1996; Emison 1996; Morison and Harvey 1997). After extensive clearing, 95% (16,700 km^2) of this land is now under cultivation (Land Conservation Council 1985), leaving a mosaic of isolated remnants on roadsides and freehold land.

Buloke is listed as depleted under the Flora and Fauna Guarantee Act (Morison and Harvey 1997). Its failure to regenerate, especially in northern areas (Flux 1998), and the death of mature trees (W. Jones *pers. comm.*; D. Burgess *unpubl. data*) is cause for concern. Decline and death of native trees in isolated remnants has been attributed to increased infestation by mistletoes and insects (Loyn 1987; Wylie *et al.* 1993) resulting from vegetation removal (Thomas 1997). This review will discuss the gall and mistletoe parasites of Buloke, and will consider their implications for the survival and conservation of Buloke in the Victorian Wimmera.

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Insect-induced galls

Insect-induced galls are atypical growths produced in response to insect feeding on a host plant (Mani 1992; Austin and Dangerfield 1998). Growth forms range from almost normal plant organs to bizarre and complex abnormalities (Mani 1992). Gall shape and morphology is often unique to the inducing insect species (Rohfritsch 1992), facilitating its identification (Manners 1993). Most gall-inducers are host specific (Dreger-Jauffret and Shorthouse 1992), the result of a prolonged evolutionary association (Roskam 1992). Galls are physiological sinks, drawing photoassimilates from the plant into specialised nutritive cells that supply the gall insect (Rohfritsch 1992; Ananthakrishnan 1998).

Recorded gall-inducers of *Casuarina* and *Allocasuarina* species are few compared to some other major Australian plant genera. They include three closely related species of Thysanoptera, which produce bulbous woody galls on tree stems (Jones and Elliot 1995; New 1997), species of Hymenoptera which form cone-like bud galls on *Casuarina quadrivalvis* (French 1911), and *Skusemyia allocasuarinae* (Diptera), which damages lateral branch buds of *Allocasuarina verticillata* (Kolesik 1995). The coccid *Cylindrococcus* spp. form galls similar in appearance to *Allocasuarina* fruit on host stems (Gullan 1984; Jones and Elliot 1995).

Cylindrococcus casuarinae Maskell is the only gall-inducer recorded on Buloke, and is in fact specific to *Casuarina* and

Allocasuarina (Gullan 1978, 1984). *Cylindrococcus* spp. are by far the most intensively studied gall-formers on Casuarinaceae. Initially *Cylindrococcus* was raised to include *C. casuarinae* and *C. spiniferus* (Maskell 1892), then two further species, *C. amplior* (Maskell 1893) and *C. gracilis* (Fuller 1897), were reported from *Casuarina* in Australia. However, Gullan's study (1984) of the gall type and adult female morphology of these four species revealed insufficient features to support this separation. She therefore reclassified them into two 'species-pairs', *C. amplior* being synonymised with *C. casuarinae*, and *C. gracilis* with *C. spiniferus*.

The lifecycle of *C. casuarinae* is typical of the coccids. The female, a sessile, plump, pinkish insect, about 0.4 cm long when fully grown, occupies the central gall cavity throughout her life (Jones and Elliot 1995). Small, six legged larvae move out through an opening in the gall, migrate along the stem, and form feeding attachments (McKeown 1942). The introduction of insect saliva into the stem stimulates host cell growth, causing the stem to expand and surround the larva (McKeown 1942; McMaugh 1994). The male, in contrast to the large degenerate female, undergoes complete metamorphosis into a small, gall-independent insect, with a single pair of wings, non-functional mouthparts and long external genitalia (Gullan 1978). It escapes through an opening in the gall (McKeown 1942), then fertilises a female by penetrating between the bracts of the female gall with its long external genitalia (Gullan 1978).

Male and female galls are generally found on the same stem (Gullan 1984) and are often densely aggregated, reflecting the limited dispersal of the independent larvae. The mature female gall of *C. casuarinae* closely mimics the fruiting capsules of *Allocasuarina* species (Jones and Elliot 1995), the galls being conical to fusiform, 10-32 mm long, widest (2-15 mm) towards the base, and with a stalk 1-5 mm long. The gall body is grey, glabrous or pilose, with brownish apex and basal bracts. The body consists of 4-6 thickened bracts that taper to the pointed apex, and the base is surrounded by 6-15 whorls of leaf-like bracts that become smaller towards the stalk (Gullan 1984). The male gall is similar in structure to that of the female, but is distinguished by its slender shape (maximum length 17 mm, maximum width 2.5 mm) and extremely attenuate bracts (Gullan 1978).

Gullan (1984) found that mature galls of *C. casuarinae* range in shape from broad to slender, with the two extremes being most common. The broad gall, with a maximum diameter of 4-15 mm, is of the form *C. amplior* and the slender gall, maximum diameter 2-7 mm (usually <5 mm) is of the form *C. casuarinae*. Although galls broaden with maturity, this does not account for the observed morphological variability. Nor does host plant response cause gall variability, because galls of both types were collected from a single specimen of Sheoak, *Allocasuarina verticillata* (Gullan 1984).

Cylindrococcus casuarinae is widely distributed (although infrequent) in south-eastern Australia and in the south-west of Western Australia. Gullan (1984) ruled out geographic variation as the cause of size variability, even though galls from coastal localities were often thinner than those collected inland. Galls growing on Buloke in New South Wales were of the broad form only; for example, collections from Burrewarra Point contained only broad galls, while both slender and broad galls were collected from Sheoak. This suggests that the potential for infestation of Buloke by the slender gall was present, but was either not expressed or not recorded. Gullan (1984) suggested that variation in gall form results from the dioecious nature of *Allocasuarina* spp., galls growing on male and female plants differing in size. This hypothesis has not been thoroughly tested, but Wright (*unpubl. data*) observed both slender and broad galls on Buloke in the eastern Wimmera of Victoria, an area not sampled by Gullan. Furthermore, slender galls were found on both sexes of Buloke, providing evidence to reject Gullan's hypothesis. Since Gullan's collections were primarily from Sheoak, conclusions regarding the associations between *C. casuarinae* and Buloke must still be tentative. Further research, based on a larger host sample and geographic distribution, is needed to understand this morphological variation.

There is little information about the effects of *Cylindrococcus* spp. on the host plant. Gullan (1978) noted that galls of *C. spiniferus* arose from the growing tips of branchlets. In the absence of compensatory growth, termination of tip growth would reduce the photosynthetic capacity of the plant. Deleterious effects on growth and reproduction might also result from the physiological sink effect of galling, especially under conditions of stress. This topic is largely unresearched, but is important, especially in view of the decline and depletion of Buloke noted earlier.

Control of *Cylindrococcus* spp. has received little attention, as Buloke is not an agricultural or economic species. Jones and Elliot (1995) suggested that in an undisturbed environment *Cylindrococcus* galls are controlled by parasitic wasps. Artificial methods of control, including chemical control and removal of galls by hand (Jones and Elliot 1995; McMaugh 1994), have been largely unsuccessful. Fire is known to eliminate some phytophagous insects (Gill 1996), but the impact of burning on the host trees and ecosystem may make this method of control unadvisable. Applications of fertiliser can reduce insect attack (Hadlington and Johnston 1998), but the effectiveness against *Cylindrococcus* has not been assessed.

In addition to the gall-formers, plant galls support whole communities of insects, including natural enemies. A study by Austin and Dangerfield (1998) on gall wasps of *Banksia marginata* revealed that 57% of sampled galls were occupied by other insects, including 11 species of Hymenoptera, three of Coleoptera and one of Lepidoptera. The relationships between these secondary colonisers are poorly understood and there are no descriptions of the insect communities in *Cylindrococcus* galls. This highlights the limited knowledge of the ecology of *Cylindrococcus* galls and the need for further research, especially before undertaking gall control, as chemicals that remove natural control agents within the gall may exacerbate rather than reduce galling.

Mistletoe parasites

Mistletoes are highly specialised and geographically widespread hemi-parasitic plants. Australia has 86 species of native mistletoe, distributed in forests, woodlands and shrubland communities throughout the continent (Reid 1997).

The response of a host plant to mistletoe parasitism varies from spectacular growth abnormalities to almost no visible symptoms (Calder 1997). Mistletoes compete for water, inorganic ions and metabolites (Ehleringer *et al.* 1985; Downey *et al.* 1997), causing reduction or inhibition of host growth (Nicholson 1955; Reid *et al.* 1994) and defoliation and replacement of host foliage with mistletoe (Kenneally 1973). Mistletoe infection may also produce imbalances in growth regulation by the host, and introduce toxins through the haustorial interface (Stewart and Press 1990; Downey *et al.* 1997).

Damaging levels of mistletoe infestation both in agricultural environments and in forests in Victoria have been recorded since the early 1900s (Patton 1917; Kerr 1925; Calder 1997; Fagg 1997). Nevertheless, host death was uncommon, and was generally attributed to drought, salinity, senescence or rural dieback (Hart 1961). The interaction between mistletoe damage and these factors has not yet been assessed.

Of the 12 mistletoe species native to Victoria only two are recorded on Buloke (Calder 1997). *Amyema linophyllum* or Buloke Mistletoe is found only on *Allocasuarina* and *Casuarina* spp. (Lunt *et al.* 1998). This species shows striking mimicry, its leaves being so similar to the Buloke branchlets that it is easily overlooked, except when in flower (Fletcher 1996; Lunt *et al.* 1998). *Amyema linophyllum* is considered vulnerable in Victoria (Lunt *et al.* 1998), although Calder (1983) suggested that mimicry has caused its under-representation in many surveys. Fletcher (1996) reported heavy infestation of *A. linophyllum* on roadside Buloke and Calder (1997) described the species as 'a local problem' in areas of Victoria. This suggests either a recent increase in localised populations of *A. linophyllum*, particularly in disturbed remnants, or improved recognition of the mistletoe species.

Lysiana exocarpi, the Harlequin Mistletoe, has a much wider host range

than *A. linophyllum*, including species of *Casuarina, Acacia, Cassia, Exocarpus*, exotic trees and even other mistletoes (Calder 1997). It is easily recognised on Buloke due to the bright green, broader foliage, and the dense clumps that can weigh down the Buloke branches. Large dead haustoria are common on fallen Buloke limbs, suggesting limb abscission in response to mistletoe parasitism (Race and Stelling 1997).

Harlequin Mistletoe is widespread and abundant, but is not regarded as a problem species. However, Calder (1997) noted that reports of heavy infestations are common, suggesting that parasitism by *L. exocarpi* may be increasing. Population explosions of mistletoe plants along roadside verges and disturbed vegetation remnants are well documented in Australia (May 1941; Kenneally 1973; Norton and Smith 1999). For example, Lamont and Southall (1982) recorded ten times as many mistletoe (*Amyema preissii*) individuals per potential host (*Acacia acuminata*) along a roadside than in an adjacent nature reserve.

Increased mistletoe infestation of tree species on roadsides and in disturbed environments has been attributed to various causal factors, depending on the locality and vegetation type. These include increased water run-off from roads (Norton and Smith 1999), increased nutrient availability (Cale and Hobbs 1991; Van Schagen *et al.* 1992), reduced incidence of hot fires (May 1941; Gill and Moore 1993; Gill 1996) and increased host stress due to drought, insect or fungal attack and soil compaction (Calder 1983). Birds play an important role in mistletoe dispersal; reduced numbers of perching sites in an area may encourage flight along roadside corridors (Lamont and Southall 1982; Saunders and de Rebeira 1991), while ageing host trees provide conditions favourable to the Mistletoebird *Dicaeum hirundinaceum* and other pollinating bird species (Calder 1983). If these birds in turn displace mistletoe control agents, such as possums, defoliating insects and other frugivorous birds that are less effective in dispersing mistletoe seed (Thomas 1997), an increase in mistletoe population may result. Physical removal of mistletoe has been minimal due to the risks and costs involved (Fagg 1997). Fletcher (1996) recorded an increased incidence of mistletoe on roadside Buloke, but was unable to identify the cause.

The effects of mistletoe parasitism on *Allocasuarina* spp. have not been reported, but studies on *Eucalyptus* hosts (Kerr 1925; Nicholson 1955; Race and Stelling 1997) indicate that mistletoe reduces vigour and increases host mortality. Preston (1977) and Knutson (1983) found an inverse relationship between host vigour and the number of mistletoe plants per host, and Knutson (1979) concluded that damage to mistletoe-infested trees was due to parasite induced water deficits. In a survey of farm trees in northern NSW, 24% of heavily infested *Eucalyptus blakelyi* died in 33 months (Reid *et al.* 1994). In trees with 50% of crown occupied by mistletoe, the average increment in branch diameter was about half that of uninfested trees.

There is also evidence, however, that mistletoe parasitism is not harmful to the host. Assessment of 208 eucalypts carrying indigenous mistletoes around Melbourne found that 57% were healthy and there was no correlation between host health and the number of mistletoe plants (Race and Stelling 1997). These authors concluded that mistletoe is not necessarily harmful, but forms a symbiotic relationship with the host in times of low environmental stress. The suggestion that mistletoe may only be detrimental in times of stress has received limited attention. Stewart and Press (1990) noted that high transpiration rates of xylem feeding mistletoes affect the water balance of the host, but concluded that the level of water stress depends on water availability; in a dry environment, mistletoe parasitism may kill the host, while in areas of high rainfall, the effects may be negligible. Similarly, Ullmann *et al.* (1985) found that water use by mistletoe is disadvantageous only if the host is severely damaged or senescent. In areas of minimal ecological stress, the minor impact of mistletoe supports the conclusion that mistletoe is not a problem but rather a symptom of ecological imbalances (Thomas 1997).

Conclusions

Galls

Although the gall-inducers on Buloke have been identified and studied since 1892, questions remain about the morphological variability of the galls, while their effect on Buloke vigour and mortality has not yet been investigated. These effects will depend on the level of infestation, which in turn may be influenced by host vigour and thus by environmental factors. Surveys of gall infestation in Buloke remnants in conjunction with environmental assessments are therefore a high priority. In addition, research is needed to study the lifecycle of *C. casuarinae* in relation to the phenology of Buloke growth and reproduction, and assess the biocontrol activity provided by secondary gall colonisers. Only then will informed decisions be possible regarding the necessity or otherwise for gall management and appropriate management methods. In the meantime, restoration and protection of these old and isolated Buloke remnants would be prudent.

Mistletoe

It is unclear whether mistletoes pose an immediate threat to the conservation of Buloke, but the potential for high rates of parasite recruitment and host tree mortality is present, especially in damaged roadside corridors and in isolated stands. On-going surveys of the distribution and abundance of mistletoe on Buloke together with assessment of host vigour are needed to determine whether the host-parasite relationship is changing. It must also be recognised that *A. linophyllum* and *L. exocarpi* are important components of the indigenous flora and in turn provide habitat and food for indigenous fauna (Yan 1993). Hence mistletoe control methods cannot be based simply on eradication, but must focus on management to restore the ecological balance and sustain a healthy equilibrium between mistletoe and their Buloke hosts. This requires ecological and physiological studies of the interaction between the mistletoe species and Buloke.

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Opportunistic Vertebrate Predation by the Squirrel Glider *Petaurus norfolcensis*

Greg J. Holland[1]

Abstract
The Squirrel Glider *Petaurus norfolcensis* is classified as an exudivore/insectivore feeder, with staple dietary items including insects, insect exudates and plant exudates. During a study of the foraging ecology of the species in northern Victoria, an adult female glider was observed to harass a nesting Common Bronzewing *Phaps chalcoptera*, ultimately removing the bird before consuming eggs within the nest. A description of this observation is provided and vertebrate predation by the Squirrel Glider is discussed in relation to other published accounts. Vertebrate predation by the Squirrel Glider is considered infrequent and opportunistic, but may provide an additional protein and energy source for lactating females. (*The Victorian Naturalist* **118** (4), 2001, 123-126.)

Introduction

The Squirrel Glider *Petaurus norfolcensis* (Fig. 1) is an arboreal, gliding possum of eastern Australia with a distribution extending from northern Queensland to Victoria (Menkhorst 1995; Suckling 1995a). The species is considered endangered in Victoria and is listed under the Victorian *Flora and Fauna Guarantee Act 1988* (DNRE 2000).

The diet of the Squirrel Glider is similar to that of its Australian congeners the Sugar Glider *Petaurus breviceps*, Mahogany Glider *Petaurus gracilis*, and Yellow-bellied Glider *Petaurus australis* (Menkhorst 1995; Strahan 1995). All are classified as exudivore/insectivore feeders with dietary items including plant exudates (e.g. eucalypt sap), insect exudates (e.g. honeydew), and insects themselves (Smith 1982; Goldingay 1986; Kavanagh 1987; Howard 1989; Quin *et al.* 1996; Carthew *et al.* 1999; Jackson 2001). More specifically, studies of the diet of the Squirrel Glider have found the species to rely on nectar and pollen, sap, *Acacia* gum, *Acacia* seeds and arils, fruit, lichen, manna, honeydew, and invertebrates as food sources (Menkhorst and Collier 1987; Suckling 1995a; Holland 1998; Sharpe and Goldingay 1998). The diets of all Australian petaurids tend to be opportunistic, with the importance of individual dietary items varying both temporally and spatially.

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The following is a description of an observation of an individual Squirrel Glider preying upon a vertebrate animal. Such accounts are rare in the literature for both Squirrel Gliders and petaurids in general, particularly concerning free-ranging animals. The observation was made during a detailed study of the foraging ecology of the species in northern Victoria.

Vertebrate predation observed in the Squirrel Glider

To study the foraging ecology of the Squirrel Glider, individual animals were fitted with radiocollars and data was collected via direct timed observations. The study was conducted along a strip of remnant roadside vegetation in the northern plains of Victoria, near Euroa. Vegetation along the road reserve forms an open woodland dominated by Grey Box *Eucalyptus microcarpa* (Ross 2000).

On the night of 12 November 1998, observations were made of an adult female

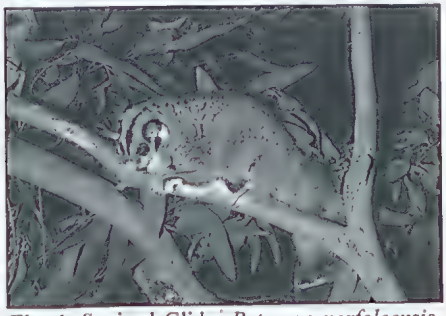

Fig. 1. Squirrel Glider *Petaurus norfolcensis*. Photo by John Seebeck.

glider, known to be carrying a single, furless pouch young, approximately 2.5-3.0 cm in length (crown-rump).

At 2228 hours the glider approached a nesting Common Bronzewing *Phaps chalcoptera* (Higgins and Davies 1996). The nest was located in the fork of a near horizontal Grey Box branch approximately 10 m above the ground. The Common Bronzewing became very distressed as the glider sniffed the edge of the nest. Facing the glider, the bird rapidly flapped its wings while remaining on the nest. This behaviour did not deter the Squirrel Glider, which then forced its head beneath the bird for a short period. At 2231 hours the glider moved past the nest and sat stationary on the same branch, approximately one metre distant. The Common Bronzewing ceased its wing flapping and remained on the nest. After one minute the glider again approached, sniffing the nest and pushing its head under the bird as above. Again the Common Bronzewing became severely agitated and resumed its wing flapping. This continued for a period of one minute before the Squirrel Glider again moved approximately one metre past the nest and sat stationary. After a further one minute of inactivity, the glider moved towards the nest once more and continued harassing the Common Bronzewing. After 20-30 seconds the Common Bronzewing vacated the nest, flying to a nearby tree. The Squirrel Glider then moved approximately half a metre from the nest and sat stationary for one minute. It then moved back, placing most of the front half of its body into the nest. For a period of 10 minutes the glider remained in this position, moving only its head in a licking motion. During this time it was inferred that the Squirrel Glider broke the shell and consumed the contents of eggs within the nest. At 2246 hours the glider left the nest and engaged in other activities.

Inspection of the nest the following morning found no trace of eggs. However, an eggshell was found on the ground almost directly beneath the nest. This eggshell had a neat, narrow incision on one side and was completely void of contents. It is possible that this egg had been consumed by the Squirrel Glider the previous night.

Discussion

Although classified as an exudivore/insectivore feeder, this observation indicates that the Squirrel Glider is capable of preying upon the eggs of nesting birds. Similar accounts of vertebrate predation by free-ranging Squirrel Gliders are uncommon. Winter (1966) described a remarkably similar observation of a Squirrel Glider attacking a nesting Magpie-lark *Grallina cyanoleuca* near Brisbane, Queensland. Prior to consuming the eggs the glider bit the adult bird and lifted it from the nest using its teeth. The Magpie-lark later died from injuries inflicted by the glider. In their investigation of the diet of the Squirrel Glider in Victoria, Menkhorst and Collier (1987) found feather fragments in the faecal samples of several individuals. The absence of bone fragments created doubt as to whether the gliders in question had killed and eaten roosting birds. Hence, it was hypothesised that feathers may have been inadvertently ingested while consuming bird eggs (Menkhorst and Collier 1987).

Fleay (1947) described the carnivorous tendencies of Squirrel Gliders, Sugar Gliders, and hybrids of these two species in captivity. All were observed to attack small birds placed in their enclosures. Sugar Gliders were also responsible for the consumption of a House Mouse *Mus domesticus*. Published accounts of vertebrate predation by wild Sugar Gliders are rare, despite much work having been done for the species. McKenzie *et al.* (1977) observed a Sugar Glider eating a Peaceful Dove *Geopelia striata* in the Kimberley region of Western Australia.

The above indicates that both the Squirrel Glider and Sugar Glider include avian prey in their diet, if only infrequently. Both are known to attack small birds in the wild and in captivity, and there are now two accounts of free-ranging Squirrel Gliders consuming bird eggs. There is no published information relating to vertebrate predation for the Mahogany Glider or Yellow-bellied Glider.

All previous accounts of avian predation for both the Squirrel Glider and Sugar Glider have involved a direct physical attack on an adult bird. In this observation, the Squirrel Glider made no attempt to

physically attack the nesting Common Bronzewing. It is possible that the larger size of the Common Bronzewing (28-36 cm, 320-350 g; Higgins and Davies 1996), in relation to the Squirrel Glider (18-23 cm excluding tail, 190-300 g; Suckling 1995a), deterred the glider from making a direct physical attack. The Magpie-lark (26-30 cm, 75-95 g; Pizzey and Knight 1999; W. Boles, Australian Museum, Sydney, *pers. comm.*) is considerably lighter than the Common Bronzewing, and is the only species recorded as a victim to a Squirrel Glider attack in the wild (Winter 1966). Similarly, recorded avian victims of the Sugar Glider (16-21 cm excluding tail, 95-160 g; Suckling 1995b) have been comparatively small (Peaceful Dove: 20-24 cm, 41-66 g; European Blackbird *Turdus merula*: 25-25.5 cm, 75-95 g; Fleay 1947; McKenzie *et al.* 1977; Boles 1988; Higgins and Davies 1996).

The diet of petaurid possums is considered to be low in protein, with plant and insect exudates such as sap and honeydew being rich in carbohydrates but containing little protein. Hence, such possums must include protein-rich food items such as arthropods and pollen in their diet to meet their protein demands (Smith 1982; Quin *et al.* 1996; Jackson 2001). Protein is a particularly important dietary component during reproduction, with lactating females requiring increased protein intakes (Smith 1982; Henry and Suckling 1984; Suckling 1984; Goldingay 1986; Sharpe and Goldingay 1998). Several authors have found that petaurids time their reproductive efforts so that lactation occurs when protein-rich food sources (i.e. pollen and/or arthropods) are most abundant (Smith 1982; Suckling 1984; Quin 1995; Jackson 2001). Smith (1982) observed the Sugar Glider to forage for arthropods in preference to plant exudates while lactating, despite the abundance of exudates during the same period.

The Squirrel Glider in this observation was a female carrying a single pouch young, and most faecal samples identified as containing feather fragments by Menkhorst and Collier (1987) were from female gliders. Female gliders may engage in egg predation when provided with the opportunity in order to facilitate lactation. Not only are bird eggs rich in protein, they are also rich in fats that would assist lactating animals in satisfying increased energy demands (Green 1997). The risk of injury associated with attacking and/or removing the parent bird may make egg predation less worthwhile for male gliders and non-lactating females given their lower protein and energy requirements.

Vertebrate predation by the Squirrel Glider (and Sugar Glider) appears to be opportunistic. Despite observing Squirrel Gliders for in excess of 3 000 minutes over the course of a year, only one incidence of vertebrate predation was recorded. Hence, it is unlikely that the Squirrel Glider actively searches for vertebrate prey in the course of general foraging activities. Instead, it is concluded that gliders capitalise on vertebrate prey only when suitable targets are encountered by chance whilst foraging for more abundant and reliable food sources. This explains the dearth of records for such behaviour.

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Human and Natural Impacts on the Upper Yarra Region with Reference to the Yellingbo Nature Conservation Reserve: a Review

Sabine Kasel[1]

Abstract

The Upper Yarra Valley and Dandenong Ranges region has a rich and diverse social history. Past and current land management activities, including gold mining, timber harvesting, agriculture, and urban development, have fragmented and degraded the landscape. Currently, there is a wide range of agricultural and horticultural activities within the region, some of which are in decline (e.g. dairy farming) whilst others are expanding rapidly (e.g. grape production).

The Yellingbo Nature Conservation Reserve is situated within the Shire of Yarra Ranges and is best known as the last remaining habitat of the Helmeted Honeyeater *Lichenostomus melanops* subsp. *cassidix*, Victoria's official State bird emblem. The general land use activities within the Shire of Yarra Ranges are reflected in changes in land use in areas bordering the Yellingbo Nature Conservation Reserve. Over the past fifty years there has been a marked reduction in the area of native forest (from 47 to 13%) and a corresponding increase in pasture based activities (from 53 to 83%) and some intensive horticulture (0 to 4%). With current revegetation strategies and ongoing land purchases, there will be a gradual increase in forested areas bordering the Yellingbo Nature Conservation Reserve. (*The Victorian Naturalist* **118** (4), 2001, 127-139.)

Introduction

In 1982 a report was produced for the then Fisheries and Wildlife Division entitled *A Historical Survey of Yellingbo* (Curtis 1982). The following review is loosely based on this report but provides more detailed historical information and has been substantially updated to incorporate more recent events and material.

The Yellingbo Nature Conservation Reserve (YNCR) is located approximately 48 km east of Melbourne (37°47' S, 145°32' E; altitude 70-120 m above sea level) within the Shire of Yarra Ranges, a region that covers a total of 276 000 ha. The Shire of Yarra Ranges was formed in December 1994 and now oversees the majority of land previously included within Shires of Lilydale, Sherbrooke, Upper Yarra and Healesville (Fig. 1).

This paper begins with a general description of the Yellingbo Nature Conservation Reserve. This is followed by the natural history of the region that includes the origin of the township of Yellingbo, land settlement and past natural events such as fires, floods and droughts. The physiography, geology, and soils of the region are then discussed. The paper concludes with a general description of land use activities within the Shire of Yarra Ranges and a historical account of changes in land use activities surrounding the YNCR.

Yellingbo Nature Conservation Reserve

The YNCR was created in May 1965 to protect the habitat of one of the few remaining populations of the Helmeted Honeyeater, *Lichenostomus melanops* subsp. *cassidix* (nomenclature after Christidis and Boles 1994), Victoria's bird emblem. At that time, the YNCR was only 170 ha in size but has since grown with subsequent purchases to 591 ha. The YNCR now supports the last remaining population of the Helmeted Honeyeater (approximately 100 individuals) following the extinction of relict groups at Cardinia Creek and near the township of Cockatoo around the time of the 'Ash Wednesday' wildfires in February 1983 (Smales *et al.* 1990).

YNCR is situated in a sheltered valley system between the Dandenong and Great Dividing Ranges, the former providing a high-rainfall catchment for the permanent streams in the YNCR. The climate is cool-temperature. Mean daily maximum temperatures range from 13.6°C in winter to 25.6°C in summer (YNCR 1988-1994

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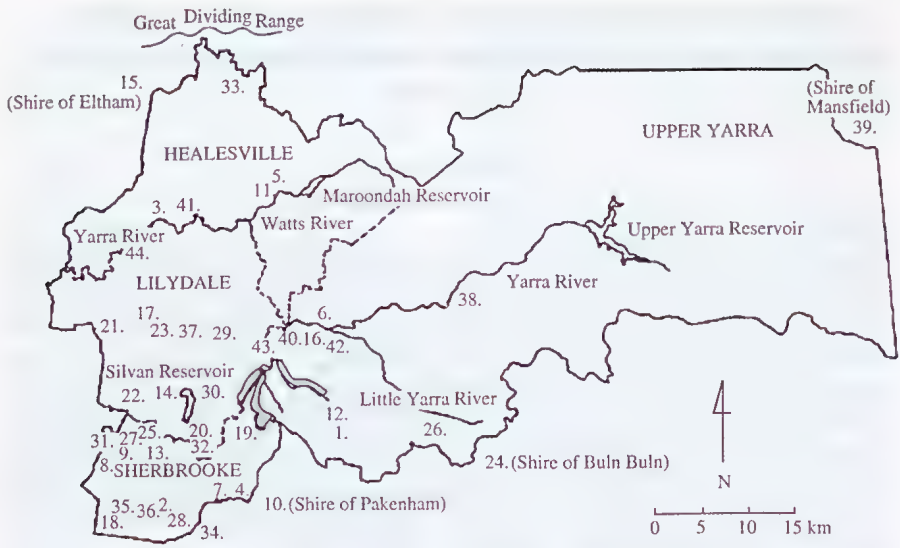

Fig. 1. The Shire of Yarra Ranges. Solid line major rivers, Dotted line boundaries of the former Shires of Lilydale, Healesville, Sherbrooke, Upper Yarra and Dandenong Ranges, Shaded region The Yellingbo Nature Conservation Reserve. Localities mentioned in the text are indicated by corresponding numbers. Localities: 1. Beenak; 2. Belgrave; 3. Christmas Hills; 4. Cockatoo; 5. Coranderrk; 6. Don Valley; 7. Emerald; 8. Ferntree Gully; 9. Ferny Creek; 10. Gembrook; 11. Healesville; 12. Hoddles Creek; 13. Kallista; 14. Kalorama; 15. Kinglake; 16. Launching Place; 17. Lilydale; 18. Lysterfield; 19. Macclesfield; 20. Monbulk; 21. Mooroolbark; 22. Mt Dandenong; 23. Mt Evelyn; 24. Noojee; 25. Olinda; 26. Powelltown; 27. Sassafras; 28. Selby; 29. Seville; 30. Silvan; 31. The Basin; 32. The Patch; 33. Toolangi; 34. Upper Beaconsfield; 35. Upper Ferntree Gully; 36. Upwey; 37. Wandin; 38. Warburton; 39. Woods Point; 40. Woori Yallock; 41. Yarra Glen; 42. Yarra Junction; 43. Yellingbo; 44. Yering.

inclusive; DNRE *unpubl. data*). The annual rainfall is approximately 1 100 mm which falls throughout the year with peaks in winter and spring. There are generally fewer than ten frosts each year but fogs may persist for much of an estimated 50 to 100 days each year (McMahon and Franklin 1993).

The YNCR encompasses narrow strips of riparian and swamp vegetation along the Woori Yallock, Cockatoo, Macclesfield and Sheep Station Creeks (Fig. 2) that are dominated by Mountain Swamp Gum *Eucalyptus camphora*, Swamp Gum *E. ovata* and Manna Gum *E. viminalis* (nomenclature for all flora species after Ross 1996). YNCR includes the largest and most intact example of *E. camphora* swamp woodland in Victoria, a 170 ha drainage basin along the lower reaches of the Cockatoo and Macclesfield Creeks (McMahon *et al.* 1991). This swamp is subject to seasonal inundation which lasts from three to ten (or more) months per year (McMahon and Franklin 1993). Much of the swamp was formerly used for agriculture (Backhouse 1987).

Tree decline is a serious problem throughout the YNCR and most of the eucalypts (*E. camphora, E. ovata, E. viminalis,* Green Scent Bark *E. fulgens*) display symptoms of decline or dieback (McMahon *et al.* 1991). In 1991 an estimated 25-30% of the eucalypt canopy was affected by dieback (McMahon *et al.* 1991). Dieback is particularly severe within the swamp and in 1991 approximately 30% of the swamp was affected by dieback (McMahon and Franklin 1993). Since 1991 a further 12% of the swamp has been affected by dieback, and 20% of the affected trees (predominately *E. camphora*) are dead (Carr 1998; Craigie *et al.* 1998). Most of the land bounding the YNCR is cleared

Fig. 2. The Yellingbo Nature Conservation Reserve. Solid line, water course, Dotted line, reserve boundary (as it stood in 1995), Dashed line, Melbourne Water pipeline.

or semi-cleared farmland and uses include cattle grazing, hobby farming, market gardening, poultry and pig farming. A large artificial lake adjacent to the northern end of the Cockatoo Creek forms part of a holiday ('Way of Life') camp. Two Melbourne Water pipeline easements cut through the YNCR; one crosses the Cockatoo Creek in the central part of the YNCR, while the other runs adjacent to the northern end of the Woori Yallock Creek before it crosses the YNCR just after these two creeks converge (Fig. 2). The Macclesfield-Woori Yallock Road runs between the Woori Yallock and Cockatoo Creeks and crosses the YNCR just north of their junction.

History

Aborigines

Immediately prior to the arrival of European settlers, four major groups of Aborigines occupied what is now the Shire of Yarra Ranges. The Aboriginal groups included the Boonurrong, Moonoba Ngatpan, Taoungurong and Wawurrong (or Woewurrong) people (Smyth 1878). Most of the region (which includes Yellingbo) was the territory of the Wawurrong people and was more or less continuously inhabited. The Wawurrong laid claim to all the land included within the basin of the Yarra River and the Dandenong Ranges. The boundaries followed the course of the Maribyrnong River in the west, the dividing range to the north, the mountains containing the sources of the Yarra in the east and the mountains lining the Yarra basin in the south.

In 1838, the number of Aborigines who inhabited the region was estimated to be 205 members of the whole Wawurrong tribe and 87 of the Boonurrong tribe. Before Melbourne was settled in 1835, the aboriginal population would have been larger, but was always small (Tansley 1978; Carroll 1988).

Archaeological evidence and reports from early European settlers suggest that Aborigines preferred the river flats around present-day Yarra Glen and Yering and the foothills around Lilydale and Mooroolbark. Mountainous areas with rough and densely-forested terrain and cold, wet winters were avoided and only visited in summer to obtain specific prod-

ucts and to maintain contact between distant tribes (Tansley 1978).

The Aborigines were a hunter-gatherer community, living well on the river flats and in the foothills where game was abundant. They were semi-nomadic and roamed the countryside in small tribal groups in search of game. Their diet consisted of animals such as possums, kangaroos, various water-birds and fish and vegetables such as the roots of small plants and a variety of fruits and seeds (Aveling 1972).

Not long after the arrival of European settlers, reserves were created for the purpose of protecting the Aborigines from the settlers, many of whom were ruthless in dealing with the Aborigines. The largest Aboriginal station in Victoria was Coranderrk, near Healesville. The reserve was established in 1863 on 930 ha of land between Badger Creek and the Watts River. In 1868, the reserve was enlarged to 1 960 ha and by 1878, the population had reached 148 (Massola 1975). In 1922 the reserve was officially closed and most of the remaining inhabitants were taken to Lake Tyers and Coranderrk was subdivided for soldier settlement.

The township of Yellingbo

Yellingbo was originally known as Claxton after James Claxton, one of the earliest settlers in this particular portion of the Yarra Ranges Shire. Claxton's title to land on the outskirts of the future township of Yellingbo became permanent in 1883 and he erected a solid weatherboard building near the Woori Yallock Creek that served as wine salon, post office and store for a number of years. Groceries were brought each week to Claxton from Lilydale by bullock wagon (Coulson 1959).

After marrying Elizabeth Parslow, James Claxton moved to Melbourne to live. By 1888 all the titles had passed to Elizabeth's brother, Henry Parslow. The locality soon became known as Parslow's Bridge, or simply Parslow's. During that period, a grocer from Seville called at the store weekly, while mail was carried by a horseback rider twice a week (Coulson 1959; Carroll 1988).

The post office, known as Parslow's, was operated for many years by members of the Parslow family. For some time the wine hall was also the post office but by 1918 had been moved to Mrs Ellen Parslow's property. A telegraph and telephone office opened there on 3 February 1921. Christopher John Parslow (nephew of the original selector) took over the post office on 14 November 1925. In the early 1940s, the original building was replaced and the post office transferred to its existing site. In March 1952 Christopher Ian Parslow took over functions in the post office. On 12 August 1946 the locality was renamed Yellingbo (which means 'today') after the last Aborigine to have frequented the district (Coulson 1959; Carroll 1988).

Land settlement

European settlement of the region began in 1837 with the arrival of the Ryrie brothers. They travelled overland from New South Wales with a large herd of cattle and settled on the lush river flats near the future site of Lilydale and called their property by its Aboriginal name, 'Yering'. They took up a grazing licence on 17 000 ha of the most fertile land between Woori Yallock and Olinda Creeks on the south side of the Yarra. Once established, the Ryries extended their grazing licence and established two outstations on the north bank of the Yarra (Marriott 1975; Tansley 1978; Curtis 1982; Carroll 1988).

A number of pastoral leases were taken up in the Upper Yarra Valley between 1835 and 1851 (Fig. 3). 'Elgars' and 'Unwins', were taken up soon after settlement and subsequent leases included: the 'Gulf' along Dixons Creek, north of the present day township of Yarra Glen; 'Christmas Hills' (which was close to the present day settlement of the same name); 'Steels Flat' along the Wandin Yallock Creek valley; and 'Solitude' along the Woori Yallock Creek valley (Marriott 1975; Tansley 1978). Of these, Steels Flat and Solitude are of most interest since they were in the vicinity of Yellingbo (Curtis 1982).

Steels Flat is believed to have been part of Ryrie's outstations (Curtis 1982) and was farmed by Robert Brierty, followed by Peter Kerr and David Mitchell (Curtis 1982). David Mitchell cleared the land, introduced English pasture species, and began dairying

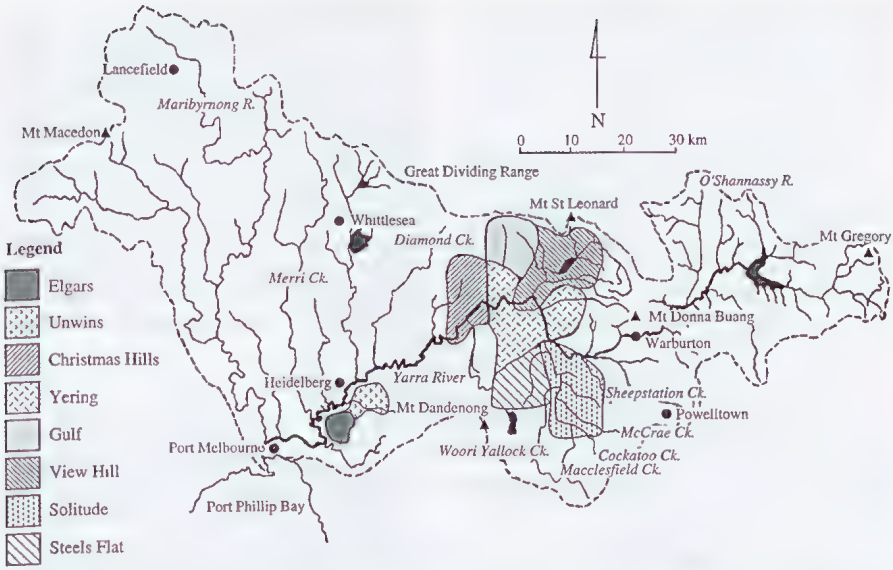

Fig. 3. Pastoral leases of the Yarra Valley, 1835-1851 (modified from Marriott 1975). The various leases are indicated by differently shaded areas (see legend). The Yellingbo Nature Conservation Reserve is located within Steels Flat and Solitude Run. This map shows the Yarra Valley defined on the basis of the watersheds of the Yarra River and its tributaries. Dashed line, catchment boundaries, Black areas, water storage reservoirs.

and cheesemaking. In the 1880s, David Syme took over the area and divided it into two parts called Killara and Dalry (Curtis 1982).

Solitude Run in the Hoddles Creek area is also thought to have been part of Ryrie's outstations (Curtis 1982). In 1846, James Cavanagh operated the 11 580 ha Solitude Run which was to change hands frequently – some nine times in 20 years (Curtis 1982). Each successive owner had the right to farm the Solitude Run, however its lower reaches, where Yellingbo is situated today, were not cleared and developed until the 1880s (Curtis 1982). The pastoralists preferred to graze their cattle on the river flats rather than in the timbered regions (Tansley 1978). The following statement held true until the days of the Land Settlement Act: 'It was only around the homesteads that the mark of the man was much apparent; here the land was cleared both for its timber and to plant kitchen gardens' (Aveling 1972). Housing was mostly made from local materials. Most of the homesteads were constructed from hand-hewn wooden slabs and had shingle roofs.

In the 1880s, the Land Settlement Act was introduced to Parliament with the aim of providing the 'everyday working man' with an opportunity of obtaining land for a low cost, under the condition that he clear and work the land. The proclamation of the act provided the impetus for 'development' of land throughout Victoria. An inspector would visit the settlements monthly to police this agreement. Clearing was slow and patchy and eventually many of the settlements were abandoned and cleared areas returned to scrub (Curtis 1982).

Gold mining

The Shire of Yarra Ranges was the site of several gold rushes. During the 1860s and 1870s there was a great deal of mining in the Upper Yarra Fields. Gold was first discovered in Emerald in November 1858 (Marriott 1975; Curtis 1982). News of the find brought some 60 miners rushing to the district at a time when the remainder of the area was populated by timber workers and pastoralists living in the foothills. Five months later a total of 1 000 miners were living on the goldfields of Emerald (set around the junction of Woori Yallock and

Menzies Creeks) (Coulson 1959; Fleet 1970; Curtis 1982). By 1861 only 52 miners remained at the Emerald Goldfields since news of fresh discoveries elsewhere 'constantly sent miners packing – virtually overnight' (Coulson 1959).

Gold was discovered at Macclesfield (south of Yellingbo) in either 1864 or 1865 when prospectors from the abandoned Emerald diggings began working their way along the creeks in the area (Coulson 1959). The original prospecting era lasted only a short period but 30 years later a second find in Smith's Creek by four men picking *Eucalyptus* leaves began a small gold rush that lasted five years. A considerable quantity of gold was removed from Macclesfield during the 1890s. The majority of the gold mining in this area was alluvial, although there were some quartz claims (Coulson 1959; Fleet 1970; Curtis 1982).

Gold mining is now a minor activity in Shire of Yarra Ranges. The only operational mine of any type is a small but inactive gold mine at Hoddles Creek (Christoff and Wishart 1994).

Saw milling

Tree fellers arrived in the Yering and Mooroolbark area in the early 1840s. By the early 1850s they had cleared the Yering and Moorolbark areas and moved up the Olinda Creek valley into the Dandenong Forest. Saw milling was a large industry by the 1920s serving the booming housing industry in Melbourne. During this time, the Gembrook, Beenak and Hoddles Creek areas were the sites of most of the mills (Tansley 1978; Curtis 1982). The number of sawmills reached a peak of 241 in 1921, and then declined steadily, especially after 1924, to 169 in 1930 (LCC 1991).

Timber from the present YNCR area was transported to the railway at Woori Yallock. A timber tramline followed the Sheepstation Creek through what is now the YNCR (Curtis 1982). Land was cleared for the construction of lines for the horse drawn trams and the felled timber was used there and then to construct the lines (Curtis 1982).

In the vicinity of the present-day YNCR office in Shaw Road, a sawmill was operated by the Moore family in the 1930s. Other properties in the area had small mills for their own use (Curtis 1982).

The disastrous fires of 1939 left a large death toll because people were stranded at the many isolated sawmills. The period of timber tramlines and isolated sawmilling settlements came to an end with the post-fire introduction of new regulations requiring that mills be located in towns. The few tramlines and isolated mills that survived the 1939 fires have decayed or have been destroyed. Currently there are 22 sawmills in the Shire of Yarra Ranges (Christoff and Wishart 1994).

The railway

In 1881 the Melbourne to Lilydale railway was completed. This opened the area to tourists and allowed local produce to be transported to Melbourne. The railway line was extended to Healesville in 1889 and boosted development of that township. Construction of a further broad gauge railway line from Lilydale to Warburton in November 1901 provided great advantages to the region surrounding Yellingbo and grazing country around Woori Yallock developed. Dairying was popular along the flats of Launching Place and Don Valley and the orchards surrounding Wandin and Sevillle became more prosperous (Tansley 1978; Curtis 1982).

Fire

The Shire of Yarra Ranges ranks among the most fire prone area in the world. Major fires swept the area in 1851, 1898, 1926, 1932, 1939, 1962 and 1983 (Table 1). The bushfires of 14 February 1926 killed seven people and large numbers of livestock. A considerable portion of the region was burnt during 1932 but those fires were minor by comparison with the 'Black Friday' fires on 13 January 1939.

The 1939 fires raged across much of Victoria burning vast areas of forest (approximately 1.4 million ha) and pasture and claiming 71 lives. The Mountain Ash *E. regnans* and Alpine Ash *E. delegatensis* forests of the Upper Yarra were severely burnt.

On 13 February 1983, the 'Ash Wednesday' bushfires again burnt through much of the Shire of Yarra Ranges. Victoria was possibly in the midst of its worst drought.

Table 1. Major fires in the forested public land of the Upper Yarra Valley and Dandenong Ranges Region (after McHugh 1991).

Date	Name	Location
1851	*Black Thursday*	Widespread
1880		Basin/Olinda
1898	*Red Tuesday*	Kallista - The Patch - Selby; Gippsland
1908		Powelltown
1913		Sassafras - Monbulk
1918		Healesville
1923		Belgrave - Upwey - Ferny Creek
1926		Monbulk; Powelltown/Healesville
1932		Powelltown
1934		Basin - Ferntree Gully
1939	*Black Friday*	Widespread
1944		Basin - Ferntree Gully
1954		Upper Ferntree Gully
1962		Basin - Sassafras - Ferny Creek; Gembrook; Olinda Creek; Mt Evelyn; Kalorama
1968		Basin - Upwey; Basin - Sassafras - Ferny Creek
1972		Lysterfield
1983	*Ash Wednesday*	Warburton/Powelltown; Belgrave South - Upper Beaconsfield; Cockatoo
1991		Warburton
1997		Mount Dandenong; Sassafras - Ferny Creek

For example, in 1982, Warburton had its lowest rainfall since 1972, with just 1 026 mm compared with the average of 1 344 mm. Inflow into the Yarra River system in spring had only been about a quarter of the average and far less than that in the previous severe drought in 1967-68.

In excess of 180 000 ha of forest and pasture were severely burnt in the Ash Wednesday fires. In the Warburton area, fire damage was severe. About 36 000 ha were burnt in the area roughly bounded by Yarra Junction, Powelltown (west of Noojee), Upper Yarra Dam and Warburton. Much of this area had burned in the 1939 bushfires and the Mountain Ash forests had regenerated in the 43 years since.

A settler in the area of Yellingbo by the name of Walsh, reported that his fences and crops were damaged severely by bushfire during 1898, when Gippsland along with much of the remainder of the State was ablaze. It is feasible then, that the 1898 fire encompassed parts of Yellingbo. Beenak, a few kilometres to the southeast of the YNCR, was badly burnt by the fire (Curtis 1982).

The major fires affecting Yellingbo were those of 1926 and 1939 (Curtis 1982). According to a local resident, Mr Alec Ferguson, the blaze of 1939 extended from Healesville to Woods Point (Curtis 1982). Spot fires erupted in the Yellingbo area, caused by falling ash. Another local resident, Mr Hubert Champion, recalls that the area ranging from Parslow's through the Cockatoo Swamp was burnt at this time and that until World War II, the swamp was deliberately burnt on a regular basis (Curtis 1982). Mining records support these interpretations; Protective Registration (a means of formally requesting protection from fires and other natural disasters) was applied for in January and April, 1939 (Curtis 1982).

No fire on the scale of the 1939 'Black Friday' has been reported for the Yellingbo area in the post World War II period. In 1962 a fire extending from Sheepstation Creek-Hoddles Creek-Gembrook, claimed the lives of four of the Ockwell family at Woori Yallock, but apparently did not burn much of the present YNCR (Curtis 1982).

Floods

Evidence of severe floods was noted by Grimes (surveyor-general of New South Wales who surveyed the shores of Port Phillip Bay) when he arrived in 1803 and houses and properties of the first settlers at Melbourne were flooded within a few years of their arrival. Between the years 1839 and 1954, a total of 80 floods were recorded for

the Upper Yarra Valley (Bureau of Meteorology 1955; Curtis 1982).

Bureau of Meteorology records indicate that on average, some part of the valley is severely flooded every two years and generally in the months of August, September and October – over 50% of all floods have been recorded in these three spring months. This is the period of greatest rainfall and heavy falls cannot be absorbed by the saturated soils. While most available information deals with the lower reaches of the valley, the alluvial flats around Yarra Glen are perhaps more susceptible to flooding than anywhere else (Marriott 1975).

One of the earliest records of flooding appeared in the 'Melbourne Age' on 16 December 1863. The whole of the Yarra delta was flooded and all the local creeks were in full flood. One man was drowned in Flinders Street in the heart of the city of Melbourne, an indication of the severity of the floods (Curtis 1982).

Since European settlement, the most severe floods in the Upper Yarra Valley were in late November and early December 1934 when a cyclonic storm brought 'hurricane winds, heavy seas and torrential rains' to southern Victoria. Communications were cut and isolated rural settlements far up the valley were literally washed away. Bridges disappeared, factories and homes were flooded, and people drowned. The Melbourne Age, 1 December 1934, described the storm as 'one of the most terrific gales ever experienced in the history of this State'. Land which now forms part of the YNCR was flooded during this time and several farmers in the region lost entire crops to flood waters (Miller and Buckland 1992).

The 1934 flood was recalled by Mr Alec Ferguson, a present-day resident of Yellingbo. According to Mr Ferguson 11 inches (275 mm) of rain fell in 30 hours (Curtis 1982). Mr Ferguson stated that 'the water was four feet above the bridge across the Woori Yallock Creek on the Warburton Highway' (now known as the 'Old Warburton Highway'; Curtis 1982). Mr Hubert Champion, whose family were amongst the early settlers of the region, recalls the damage, 'cows, horses and anything else in the path of the water was washed downstream' (Curtis 1982).

A flood on the scale of 1934 was made less likely by the 'snagging' of the Woori Yallock Creek during the 1930s Depression. In this period, drains were cut at the junction of the Shepherd and Cockatoo Creeks in an effort to reclaim swampy land for agricultural use and to further control flooding. In the early 1950s levy banks were constructed further downstream along the Cockatoo Creek in an attempt to further control water flow and reclaim 'swampy' land (Curtis 1982).

Applications for Protective Registration Certificates under the Mining Act again support the contention that the region is prone to flooding with applications concerned with excess water in: July 1909, March 1934, September 1934, January 1935, November 1936, January 1937, October 1937 and July 1939 (Curtis 1982).

Another Yellingbo resident, a member of the original Parslow family, Mr Ian Parslow, recalls that during 1958 water rose approximately two metres above the present road level on Macclesfield-Woori Yallock Road (Curtis 1982) near the confluence of Cockatoo and Woori Yallock Creeks (Fig. 2).

In 1962, floods on a scale of 1934 were made unlikely by the opening of the Upper Yarra Reservoir (see Fig. 1) that traps much of the water previously destined for the Yarra and its tributaries. Heavy local rainfall may still cause local and short-term flooding and records of the Department of Natural Resources and Environment (DNRE) show that even average rainfall could result in water covering the Sheepstation Creek Road for a distance of 50 yards (46 metres). According to Mr Hicks, who has a property on the road, floods in the area are short lived, one to two days on average (Curtis 1982).

Droughts

Droughts are less frequent than floods in the Upper Yarra Valley although their impact is more severe. The Bureau of Meteorology has recorded eight major drought periods for the Upper Yarra Valley-Port Phillip region (Table 2). In each case droughts were not confined to this region but instead were widespread throughout southern Victoria.

Table 2. Major periods of drought in the Yarra-Port Phillip region (Bureau of Meteorology 1955, 1983a, b; after Curtis 1982).

Years	Description
1895-1902	Major rainfall deficiencies, especially in 1895 when rainfall in Melbourne was 432 mm, and in 1898 when the fall was 396 mm (average was 679 mm).
1913-1914	Marked shortages of rain, between May and October 1914, rainfall in Melbourne was 203 mm; the average for that period was 334 mm.
1925-1927	From June 1925 to June 1927, rainfall in Melbourne was about half the average.
1939-1940	Good rains in early 1939 were followed by 12 months of drought, ending in December 1940.
1943-1945	Three years of below average rainfall led to severe stock losses and bushfires.
1967-1968	The most severe drought on record. Beginning in January 1967, it lasted until April 1968. Stock, crop and home garden losses were severe. Between October 1967 and April 1968, rainfall in Melbourne totalled 148 mm instead of the average of 394 mm for these months. The total rainfall for the year of 1967 was 322 mm, the driest since records began in 1855.
1972-1973	A short yet extremely severe drought which began in the winter of 1972 and lasted until late February 1973. During that time, Melbourne faced its most severe water restrictions ever. Rainfall between March and December 1972 was about half the average.
1982-1983	Melbourne's total rainfall in 1982 was 422 mm (average 659 mm); the fourth driest since records commenced and the second driest this century. The eleven month period from April 1982 to February 1983 was the driest on record over most of Victoria (338 mm). In the summer of 82/83, the rainfall total was 78 mm compared with an average of 154 mm. In 1983, Melbourne experienced its hottest February day on record, 43.2°C.

The mining Protective Registration Certificates once again provide some indication of water levels in the Woori Yallock Creek. Water shortages were recorded on the following dates: 19 November 1929, 24 November 1936, 6 February 1937, 6 December 1938, and 10 March 1939 (Curtis 1982).

Physiography

The Shire of Yarra Ranges spans two land systems. These are the *Eastern Victorian Uplands*, which cover most of the region; and the *Yarra Plains*, in the lower reaches of the former Shire of Lilydale (Rowan 1988). The southern edge of the former Sherbrooke Shire is also at the northern margin of the *Basalt Plains* region, as evidenced by a few plant species characteristic of that area such as the Zig-Zag Rush *Schoenus brevifolius* (Christoff and Wishart 1994).

The physiographic evolution of the Shire of Yarra Ranges was governed by combinations of erosion, faulting, warping and volcanic activity. Extensive areas of outcropping bedrock have given rise to areas of high elevation. Prolonged erosion has produced a step-like succession of partially preserved erosion surfaces, the dissection of which has resulted in considerable relief (McAndrew and Marsden 1973). Three main cycles of erosion are recognizable in central Victoria, culminating in turn in the Baw Baw surface, the Kinglake Surface and the Nillumbik Terrain (McAndrew and Marsden 1973). The Shire of Yarra Ranges lies within the Kinglake Surface and the Nillumbik Terrain; of these, the Nillumbik Terrain is the most important.

The Nillumbik Terrain is the prominent erosion surface as shown by the generally concordant height of ridges in the area of Silurian-Lower Devonian bedrock east and northeast of Melbourne. It rises in elevation from about 20 m at Melbourne to about 200 m at the foot of Mt Sugarloaf (40 km northwest of Yellingbo), which is part of the well-defined escarpment at the southern edge of the higher Kinglake Plateau (McAndrew and Marsden 1973). It is also present further east in the Woori Yallock Basin. The Nillumbik Terrain has been dissected by the Yarra River and its tributaries and to a lesser extent by the Dandenong Creek.

Geology

Bedrock comprises a thick sequence of folded Upper Ordovician to Middle

Devonian sediments ranging from mudstone to sandstone with mudstone dominant in the western part of the Shire of Yarra Ranges and sandstone in the east. The western and central parts of the Shire of Yarra Ranges are dominated by thick acid volcanics comprising rhyolite and rhyodacite, and acid intrusives comprising granite and granidiorite of Middle to Late Devonian age (Cooney 1979). Outcrops of Tertiary basalt are found in isolated patches between Lilydale and Hoddles Creek. The basalt is usually highly weathered in outcrops although fresh material up to 50 m thick has been recorded in drill holes (Cooney 1979). Thin Tertiary sediments underlie the basalt in some places. Deposits of Quaternary alluvium and colluvium line major streams such as the Yarra River and the Woori Yallock, Olinda, Cardinia and Dandenong Creeks.

Remnants of erosion surfaces from the Cretaceous, Lower Tertiary and Middle Tertiary ages are present within the region, indicating that such locations have undergone prolonged weathering. The many flat ridges at elevations of about 250 to 350 m reflect the now dissected Nillumbik Terrain (LCC 1973).

The majority of the YNCR lies on Quaternary alluvial deposits of gravel, sand and silt. Within the Woori Yallock Creek and Cockatoo Creek catchments, the dominant geologies are siltstones of Lower Devonian origin to the north, and siltstones of Middle to Lower Silurian origin to the south. Upper Silurian sandstones and scattered caps of Tertiary volcanics are also present. Middle Devonian granidiorite is localized near the junction of the Woori Yallock and Cockatoo Creeks (Geographical Society of Victoria 1977, 1981). The Macclesfield Creek catchment is more elevated than the Woori Yallock or Cockatoo Creek and the soils are indicative of leached duplex profiles derived from older (Devonian and Silurian rather than Quaternary) sediments. The floodplains of the creek system are areas of generally minor topographic variation (natural and otherwise) with the elevation ranging from 60 to 80 m above sea level.

Soils

At higher altitudes in the Upper Yarra Valley, soils are generally brown, friable, and gradational. At lower altitudes friable reddish and yellowish gradational soils dominate, with some acidic duplex soils in the lower rainfall areas in the west, and shallow stony soils on the steep slopes. Loams, dark clays, and yellow duplex soils dominate the river plains (LCC 1973; Rowan 1988).

Small areas of friable brown gradational soils are scattered throughout the Dandenong Ranges. Friable reddish gradational soils are more widespread, particularly on outcrops of basalt and dacite extending east to Gembrook, and have been largely cleared for agriculture. Shallow stony soils cover the steep slopes. In the lower-rainfall areas, acidic duplex soils, yellowish gradational soils and sodic duplex soils are all common (LCC 1973; Rowan 1988).

The floodplain of the Woori Yallock Creek lies on a mosaic of poorly and relatively well drained soils of alluvial origin. The soils vary from brown silty clays at the surface (0-5 cm) to clay loams at depth (50-100 cm). Soils along the Cockatoo Creek range from grey to brown silty clay loams (0-5 cm) to sandy clay loams (50-100 cm) of colluvial or alluvial origin. Sites are seasonally waterlogged and dry over the summer months. Pale grey silty clays are found throughout the soil profile (0-100 cm) along the floodplain of the Macclesfield Creek. A detailed discussion of the physical and chemical properties of soils within the YNCR is given by Kasel (1999).

Land Use

The human population within the Shire of Yarra Ranges has increased five-fold over the past 50 years with similar increases in the number of dwellings and a concomitant decrease in the number of rural holdings (Table 3).

Public land accounts for approximately 73% of the Shire of Yarra Ranges and includes most of the water supply catchments (providing 75% of Melbourne's water supply) and forested areas close to Melbourne. The bulk of publicly owned land is located within the Upper Yarra Ranges. Private land used for rural activities comprises approximately 24% of the total area within the Shire of Yarra Ranges

Table 3. Historical changes in land use within the Shire of Yarra Ranges.

Year	*1947*	*1967*	*1993*
Population	29 707[a]	55 530[a]	148 927[b]
Year	*1966*	*1976*	*1991*
Number of dwellings	18 588[c]	30 680[a]	49 583[d]
Year	*1959*	*1977*	*1993*
Number of rural holdings	1 981[e]	965[a]	477[f]
Total area of rural holdings (ha)	81 745[e]	49 530[a]	26 033[f]
Year	*1959*	*1977*	*1994*
Number of beef cattle	12 682[e]	39 905[a]	25 384[g]
Number of pigs	5 865[e]	11 527[a]	13 395[g]
Number of milk cattle	18 771[e]	9 796[a]	2 530[g]
Number of sheep	50 725[e]	10 067[a]	1 506[g]
Year	*1977*	*1990*	*1996*
Grape production (ha)	75[h]	415[i]	1 300[i]

[a] Williams (1979); [b] Christoff and Wishart (1994); [c] CBCS (1966); [d] ABS (1991); [e] CBCS (1960); [f] ABS (1994); [g] ABS (1995); [h] Phillips *et al.* (1989); [i] Business East (1997).

and urban development accounts for a further 3% (Christoff and Wishart 1994).

The wide range of rural activities within the Shire of Yarra Ranges reflects the region's climate, soil fertility, proximity to Melbourne and historical development of farming. Agricultural and horticultural activities are discussed further as they represent the most common forms of land use in areas directly adjacent to the YNCR.

Agriculture

Some 9%, or 25 000 ha of the Shire of Yarra Ranges' total area is currently devoted to agricultural land use (ABS 1994). This represents approximately one third of the area of private land in the entire shire. More than half of this land (13 740 ha, including 2 460 ha of crops and 6 480 ha of pasture) is found near Lilydale (Christoff and Wishart 1994).

Pasture-based industries (dairy cattle, beef cattle, sheep and horses) dominate agricultural land use and dairy farming has been the most intensive and profitable of these uses. Dairying is in serious decline; between 1959 and 1994, the number of milking cows fell by 90% (Table 3). Beef cattle production is now the dominant livestock industry in the Shire of Yarra Ranges (Table 3) and has been stable during the last ten years (Christoff and Wishart 1994). Sheep farming for both wool and meat is a minor and declining activity (Table 3) while equine industries (especially breeding for recreational use, harness racing and thoroughbred racing) is a large but generally unquantified land use.

Horticulture

Some 2 000 ha within the Shire of Yarra Ranges is devoted to horticultural activity. The major horticultural crops are nursery plants, flowers, vegetables, fruit orchards, berry fruits and vineyards.

Vegetable production is a significant but again a declining land use in the Shire of Yarra Ranges. Major vegetable growing areas are Silvan, Wandin, Toolangi, Coldstream and Hoddles Creek. Approximately 520 ha of vegetables are grown in the Shire. The largest crops are carrots (almost 300 ha), brussell sprouts, cabbages, potatoes and beans (Christoff and Wishart 1994).

Over the past few years fruit production has remained stable. Crops include strawberries, apples, cherries and other stone fruits such as peaches and nectarines. The wine industry is expanding and the total area of vineyards increased from 75 ha in 1977, to over 1 300 ha by 1996 (Table 3).

Land use surrounding the Yellingbo State Conservation Reserve

Land uses directly adjacent to the YNCR boundary include intensive horticulture, cattle grazing and native forest. The intensive horticulture is in the form of a 'market garden' on the eastern bank of the Cockatoo Creek at the northern end of the YNCR. The market garden is approximately 14 ha in area and the major crops grown include broccoli, cauliflower and spinach.

The general changes in land use within the Shire of Yarra Ranges are reflected in changes in land use in areas bordering the

Table 4. Historical changes in land use surrounding the YNCR (based on the length (m) of each activity with the boundary[a] of the YNCR).

Year	Surrounding land use	Length of boundary with the YNCR					
		Cockatoo Ck		Woori Yallock Ck		Total	
		(m)	(%)	(m)	(%)	(m)	(%)
1946	Forest	8 382	39	7 308	61	15 690	47
	Pasture	13 224	61	4 592	39	17 816	53
	Horticulture	0	0	0	0	0	0
1968	Forest	4 717	22	3 422	29	8 136	24
	Pasture	16 892	78	8 478	71	25 370	76
	Horticulture	0	0	0	0	0	0
1988	Forest	1 504	7	2 878	24	4 382	13
	Pasture	18 836	87	9 022	76	27 858	83
	Horticulture	1 266	6	0	0	1 266	4
1998	Forest	3 357	15	2 878	24	6 235	18
	Pasture	16 983	79	9 022	76	26 005	78
	Horticulture	1 266	6	0	0	1 266	4
Total boundary lengths		21 606		11 900		33 506	

[a] Changes in land use surrounding the YNCR were calculated with the use of the following aerial photographs: 1998 colour, 1:16 000; 1988 colour, 1:10 000; 1969 b/w 1:10 000; and 1946 b/w 1:20 0000. The length of the boundary of the YNCR was kept constant throughout the analysis and was based on the boundary as it stood in 1995 (the perimeter of the YNCR in 1995 was superimposed on the corresponding area (images) for 1998, 1988, 1969 and 1946; the actual length of the perimeter changed over this time period as land was purchased and added to the YNCR).

YNCR. There has been a marked decrease in the area of native forest and a corresponding increase in pasture based activities and some intensive horticulture. For example, in 1946, native forest bordered about 16 km of the YNCR but only 4 km in 1988 (Table 4). Conversely the area of pasture bordering the YNCR increased from 18 km in 1946 to 28 km by 1988, with a further 1 km allocated to horticulture (Table 4).

With no further land clearing between 1988 and 1998, land uses surrounding the YNCR have remained fairly constant. Whilst keeping in mind the immature state of revegetated areas, land purchases and revegetation since 1988 have increased the 'forested' area surrounding the YNCR. For example, purchase and revegetation of 'Logan's land' (which was predominantly cleared, see Fig. 2) has increased the amount of forested area bordering the YNCR by 1 853 m (Table 4). Further revegetation and land purchases will increase this figure.

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David Ashton, OAM

Dr. David Ashton was awarded a medal of the Order of Australia in the recent Queen's Birthday Honours. He is an eminent botanist known to many Field Naturalists, and has contributed enormously to the understanding and appreciation of Victorian ecology. He studied at Cambridge with Dr. Alex Watt as supervisor and continued for an additional year with a Nuffield grant. In recognition of his astounding record of 50 years' research in the 'Big Ash' (*Eucalyptus regnans*) of Victorian mountain forests, Parks Victoria prepared and erected a beautiful bronze plaque at the Toorourong Reservoir. David has a rare ability of evaluating the forest as a whole, but still including all its detailed living processes from which the reader can visualise the living forest. David's research covers many other areas of Victorian forest such as the Brisbane Ranges, the Bogong High Plains, East Gippsland, Macquarie Island, Pelican Island in Western Port Bay, and overseas in Chile. His research extends from mycorrhizae to lyrebirds.

Some years ago David was made a Fellow of the Royal Society, and he recently received the Kookaburra award by Parks Victoria and a medal from the Ecological Society of Australia. The Department of Natural Resources and Environment has just named a biodiversity award after him. David has just completed an article on the history of the McCoy Society for *The Victorian Naturalist*.

Quiet, unassuming, friendly, and with a wicked sense of humour, David is also a talented artist. Congratulations, David, from the Field Naturalists Club of Victoria.

Gretna Weste
605 Park Road,
Park Orchards, Victoria 3114.

One Hundred Years Ago

KING ISLAND.—In the agricultural columns of the *Australasian*, of 27th July, "Bruni" writes that King Island, hitherto regarded as useless has, owing to the spread of an introduced plant, become valuable for dairy farming. When the members of the Field Naturalists' Club of Victoria held their first extended "camp-out" there, in 1887 (*Victorian Naturalist*, iv., p. 129), the country was reported as being sandy, sterile, and unsuitable for grazing, but it seems that since that time some seeds of a clover-like plant, *Melilotus officinalis*, were washed ashore from a wreck on the southern coast, and, contrary to the usual custom of introduced plants, has transformed the barren wastes into splendid pasture. The island now supports a population of about 250, and boasts a general store with post-office, while a creamery is talked of, but no school, church, or hotel has yet been established. The official requirements of the island are supplied by a police trooper. In the following issue of the *Australasian*, Mr. Frank Madden, M.L.A., writes warning farmers in Victoria against trying the Melilot as a pasture plant, as it is nothing more than a useless weed. It is, however, according to Baron von Mueller, "Select Extra-Tropical Plants," a valuable honey-yielding plant.

From *The Victorian Naturalist* Vol. **XVIII**, 1901.

W. Rodger Elliot, AM

Rodger Elliot and his wife Gwen Elliot were each recenty appointed as a Member in the General Division of the Order of Australia (AM) 'for service to the horticulture of native plants, particularly through the Society for Growing Australian Plants'.

Rodger was a member of the FNCV in the 1970s and early 1980s and rejoined Club in 1995, when he was awarded the Australian Natural History Medallion. He is currently a member of the Board of the Royal Botanic Gardens, an Honorary Life Member of the Australian Plants Society, a member of the Dandenong Ranges Garden Trust, and Deputy Chair of the Advisory Committee of the Maud Gibson Trust. He is a recipient of the Australian Institute of Horticulture's Award for Excellence and the Gold Veitch Memorial Medal.

Rodger is no doubt well-known to many members as a lecturer, broadcaster and author. He was a contributor to Your Garden magazine for over 20 years, has published plant field guides, botanical booklets and a number of gardening books. His major work-in-progress, co-authored with David L. Jones, is the 'Encyclopedia of Australian Plants Suitable for Cultivation'. This unique series, when completed, will cover the flora of the entire continent.

Gwen Elliot has been invaluable in all of Rodger's endeavours, which are listed in detail in an article by Sheila Houghton in *The Victorian Naturalist* **112** (5), 1995, pp. 188-189.

Congratulations Rodger and Gwen from the Field Naturalists Club of Victoria.

Rodger and Gwen Elliot.

The Victorian Field Naturalists Clubs Association

Annual Camp

Labour Day Weekend – Friday 8 to Monday 11 March 2002

The 2002 annual camp and meeting of The Victorian Field Naturalists Clubs Association will take place at Campaspe Downs Country Resort, 7 km SW of Kyneton, Victoria over the Labour Day weekend. As the Field Naturalists Club of Victoria is organising the event, we are hoping for the support of our members through their attendance and as volunteers for various tasks before and during the campout. Mark this date in your diary and come and enjoy guided excursions and walks through Victoria's Box and Ironbark forest remnants and surrounding areas. Learn about the plants, birds, mammals, invertebrates, fungi, geology and much, much more with field naturalist colleagues from around the State.

Guest speakers during the weekend are Dr Julian Hollis on volcanic activity in Victoria with emphasis on the Newer Volcanics, Stuart Dashper on Box-Iron Forests and Marcus Ward on Logging in Wombat State Forest.

If you would like information and a booking form, please write to Dorothy Mahler, Secretary, VFNCA Camp Weekend Organising Committee, 1 Astley Street, Montmorency 3094 and enclose a business-sized (approximately 22 × 10 cm) stamped, self-addressed envelope. A deposit of $30 is required by 19 November, 2001.

Nature Photography

by Ken Griffiths

Publisher: *University of New South Wales Press, 1999. 148 pp., colour illustrations. ISBN 0868406724. RRP $29.95.*

As a keen amateur photographer I tackled this book with some enthusiasm. I was not disappointed. Nor was John (obsessive videographer and long-suffering husband) as we both found this book informative, interesting, detailed and loaded with plenty of advice and examples of what to do and not to do when photographing nature.

The book is divided into two sections; Part 1, Equipment and Accessories, delves into the camera and the main format types of SLR, rangefinder, medium and large format and digital. But the book is about SLR photography and discusses camera features, lenses, flash, light meters, film, accessories, equipment care and maintenance, even what to look for when buying used equipment.

Photos are used as examples in how to use equipment, e.g. lenses illustrated with a collection of landscapes taken with a wide-angle lens and wider apertures. All pictures are captioned with notes describing the photo, type of lens used and aperture, shutter speed and type of film. Telephoto and macro, lens and flash features are all presented in easily-digested form and accompanying photos add detail to the text, illustrating, for example, types of flash equipment available and when to use each one.

Throughout the book key words are lightly highlighted in the text. A quick referral to the index of cross-referenced topics will lead to the page number where the highlighted topic is dealt with in detail.

Part 2 deals with 'Photographing Natural Subjects' under the headings of Natural Light; Macro and Close-up Photography; Picture Faults and Technical Problems; Where to Practice your Techniques; Plants and Animals Exposed; What to Wear and Carry; and Ethics when Photographing Wildlife.

I found Part 2 particularly useful, and armed with all the knowledge acquired in Part 1 applied some of the tips during our recent trip into Western Australia. Tips for photographing in brightly lit situations like white sand so as not to under-expose (Eyre Telegraph Station), taking photos of back lit subjects (Marble Gums and their white trunks are illuminated by back lighting in the Great Victoria Desert), using macro lenses (the detail of an Ooldea Mallee in flower in the Great Victoria Desert or a Rhinoceros Beetle on the attack on the road between Rawlinna and Cocklebiddy) are all covered within.

The section 'Plants and Animals Exposed' is a handy guide with advice on photographing all creatures great and small from invertebrates to landscapes and includes useful techniques, recommended lenses for each subject, when and how to improve your photo with the use of flash, when to use fast or slow shutter speed and open or closed aperture.

The book closes with some useful tips and a list of essential items required for a day's filming and a final emphasis on the three Ps of nature photography – practice, patience and perseverance. So it's back out to the bush for me, my camera and lenses in a purpose designed backpack and a healthy dose of the 3 Ps.

This book can be used by beginning SLR photographers who will learn much from the advice and detail presented here. Experienced photographers will also find it useful to extend their knowledge and capability in nature photography.

Anne Morton
10 Rupicola Court,
Rowville, Victoria 3178.

Wildflowers of Victoria

by Margaret G. Corrick and Bruce A. Fuhrer

Publisher: *Bloomings Books. 256 pp., 840 colour plates. RRP $59.95*

This terrific book illustrates 840 native flowering shrubs and herbs of Victoria, including 50 species endemic to Victoria. The plants are presented alphabetically by family, and a brief description of the distinguishing characteristics of each family precedes the individual species description. A wide array of flowers is included from many different habitats. For example, in the Daisy family, the Asteraceae, there are 128 photographs including *Microseris* sp. 2, which is common in alpine herbfields, *Leucochrysum albicans* subsp., *Alpinum* var. *tricolor*, currently known only from road verges, Water Buttons *Cotula coronopifolia*, widespread in damp areas and Sticky Cassinia, *Cassinia uncata*, which occurs mostly in western mallee and dry forest although a distinctive form occurs on shallow, rocky ground in the alps and subalps north of Licola. This family also includes the strange and bizarre such as Ground Heads *Chthonocephalus pseudevas* and Woolly Heads *Myriocephalus rhizocephalus*.

The species descriptions include the author, the common name where available, distribution and a few habitat notes. Included are measurements of leaves, fruits and flowers, to aid identification, along with plant height. The distribution information is provided according to the natural regions of Victoria, and these are illustrated on a map taken from The Flora of Australia (1994-1999). The introduction includes a brief description of the natural regions of Victoria, with reference to where they are situated within the state. A useful addition, however, would be the inclusion of flowering dates, such information being particularly valuable for people seeking rarely seen flowering plants such as Silvery Emu-Bush *Eremophila scoparia* or Fairy Lanterns *Thismia rodwayi*.

A glossary is provided and includes detailed descriptions of many technical terms, making the species summaries easier to understand.

'Wildflowers of Victoria' has such an extensive coverage of flowering shrubs and herbs of Victoria that it makes an ideal companion to Leon Costerman's 'Trees and Shrubs of South Eastern Australia'. Costerman's book includes coverage of shrubs which are generally taller than one metre, but a slight overlap does occur with a few species: Corrick and Fuhrer have included some small acacias, and a number of trees that display a shrubby growth form, such as Prickly Bottlebrush *Callistemon brachyandrus* described as a 'shrub or small tree 2-3 metres high' and Muttonwood *Rapanea howittiana* 'a small tree to 15 metres high'.

This book is packed full with beautiful colour photographs of the kind of exceptional standard we have come to expect of Bruce Fuhrer's work, along with simply written, easy to read text. Overall, it is a very readable and informative, beautifully illustrated book. Many species occur in other states as well so this book is ideal not only for Victorians but also for those identifying plants in similar habitats within neighbouring states.

Bernadette Sinclair
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For assistance with the preparation of this issue, thanks to Karen Dobson (label printing), Dorothy Mahler (administrative assistance) and Michael McBain (web page).

The Field Naturalists Club of Victoria Inc.

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Established 1880

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Members receive *The Victorian Naturalist* and the monthly *Field Nat News* free. The Club organises several monthly meetings (free to all) and excursions (transport costs may be charged). Field work, including botany, mammal and invertebrate surveys, is being done at a number of locations in Victoria, and all members are encouraged to participate.

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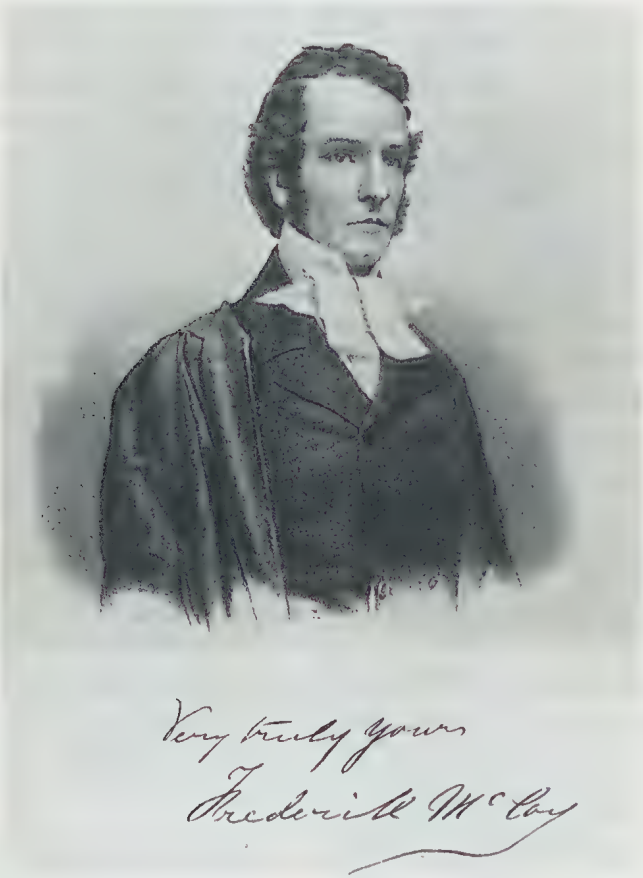
McCoy Special Issue Part One



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Foreword

Doug McCann[1]

This special two-part issue of *The Victorian Naturalist* has been produced in honour of the life and work of the nineteenth century Irish-Australian naturalist Sir Frederick McCoy. He died just over 100 years ago, on 13 May 1899, at about 77 years of age (his exact birth date remains uncertain). McCoy was the first President of The Field Naturalists Club of Victoria (1880-1883) and later, along with his renowned colleague Ferdinand von Mueller, was made a patron of the Club (1889). Although he was not directly involved in regular meetings and field excursions, the Club gained prestige and direction from his stewardship and he provided a useful link between the Club's activities and that of the Melbourne Museum of which he was first Director.

At the time of his death he was arguably Australia's most distinguished scientist. In an obituary in *The Geological Magazine*, the editor Henry Woodward stated that 'Professor McCoy was the acknowledged chief of the scientific world of Australasia' – yet today he is little known outside the specialised areas of palaeontology and the history of science.

McCoy made significant contributions to taxonomic and stratigraphical palaeontology in Ireland and England, and to palaeontology and zoology in Australia. He was the first to confirm that Australian stratigraphy correlated with that in the northern hemisphere and hence to demonstrate that the geological column was a global phenomenon. He was foundation Professor of Natural Science at the University of Melbourne and concurrently Government Palaeontologist for the Geological Survey of Victoria and Director of the National Museum of Victoria, where he built up one of the finest natural history collections outside Europe and North America.

Why then is McCoy so little appreciated? The reasons are complex and varied. McCoy was, and remains, a somewhat controversial and contradictory figure. As well as making many worthy contributions to science he was also involved in some acrimonious and long-running scientific disputes, and in some of these he fared rather badly. Authors in this issue explore aspects of some of these debates. In a sense McCoy has had to endure a 'bad press' in which his negative qualities have been emphasised (i.e., one historian referred to him as that 'bad tempered redheaded Irishman') and his more positive contributions have frequently been ignored or forgotten.

The breadth, and often the depth, of his work, however, were considerable. He was very much a product of the mid nineteenth century, when natural history enjoyed widespread popularity and standing. Taxonomy and classification were highly esteemed activities, in keeping with the then prevalent philosophy of Natural Theology. It was an era of geographical exploration and extensive collecting. There was much being discovered that was new to science and a need for it to be classified and described. McCoy was an accomplished naturalist and a very diligent taxonomic palaeontologist. Even in his day palaeontologists were beginning to specialise but the scope of McCoy's work was remarkable; he covered virtually the whole of invertebrate palaeontology as well as being competent in vertebrate palaeontology and zoology. He was also well versed in geology, botany, mineralogy, chemistry, mining technology and many of the arts.

A reassessment of McCoy's life and work has been long overdue. The current collection of papers provides a variety of viewpoints and some general as well as some in-depth studies of many aspects of his life and work. This two-part issue of *The Victorian Naturalist* offers the first exhaustive critical study of McCoy and will provide an obligatory starting point for any future work on McCoy's scientific contributions and of his life and times.

Many people have contributed towards the success of this project, in particular, the individual authors and the dedicated and patient work of the editors Merilyn Grey, Anne Morton and Alistair Evans. Special thanks are due to Professor Neil Archbold for proposing and nurturing this project from the very beginning, and for his written contributions and generous material support. The end result of the combined work of all the contributors is a landmark in documenting, analysing and understanding a pioneering period in the history of natural science in the Colony of Victoria and of the contributions of Sir Frederick McCoy, an eminent nineteenth century Victorian naturalist.

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Editors: Merilyn Grey and Anne Morton
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Foreword, *by Doug McCann* 146
Timeline: Frederick McCoy, *by Doug McCann* 148
Geological Time Scale 150
Sir Frederick McCoy FRS – an Overview, *by Malcolm Carkeek* 151
Frederick McCoy: the Irish Years, *by Thomas A. Darragh* 160
Frederick McCoy and his Contributions to Stratigraphical Palaeontology, *by Doug McCann* 165
Frederick McCoy and the Phylum Brachiopoda, *by N.W. Archbold* 178
Frederick McCoy and the University of Melbourne, *by Ian Wilkinson* 186
McCoy's 'Living Museum', *by Gwen Pascoe* 193
Professor Frederick McCoy and the National Museum of Victoria, 1856-1899, *by Carolyn Rasmussen* 200
Birds, Books and Money: McCoy's Correspondence with John Gould (1857-1876), *by Anthea Fleming* 210
McCoy and Clarke: their Dispute Over the Age of Australia's Black Coal, *by Roger Pierson* 219
Frederick McCoy's Anti-evolutionism – the Cultural Context of Scientific Belief, *by Barry W. Butcher* 226
McCoy and *Sarcophilus harrisii* Boitard, 1842 – a Diabolical Relationship, *by W.R. Gerdtz* 231
Revisiting the Real McCoy, *by N.W. Archbold* 234
Editors' Acknowledgements 159
Editors' Notes 233

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Front cover: Lithograph of Frederick McCoy by Frederick Schoenfeldt; from a series entitled 'Notable Men of the time'. Published by Hamel and Co., c. 1859. Signed by Frederick McCoy. La Trobe Picture Collection, State Library of Victoria.
Back cover: Frederick McCoy, c. early 1870s. UMA/I/1242 University of Melbourne Archives.

Timeline: Frederick McCoy (1823-1899)

Doug McCann

c. 1823	Born in Dublin (exact year of birth uncertain). Second son of Dr Simon McCoy, physician and professor of materia medica, Queen's College, Galway.
1838	First paper published in *Magazine of Natural History*: **Remarks on Mr. Eyton's arrangement of the Gulls**.
1839	Arranged the collections of the Museum of the Geological Society of Dublin and became a member of that Society. (The Catalogue of the Museum published 1841 – McCoy's first publication on fossils.)
c. 1840	Engaged by Sir Richard Griffith to determine fossils collected by Griffith and the staff of the Boundary Survey for a Geological Map of Ireland.
1841	Named and catalogued for sale shells and fossils of the Henry Sirr Collection. Curated collections of the Royal Dublin Society and the Geological Society of Dublin. First met Adam Sedgwick.
1843	Married Anna Marie Harrison in Dublin.
1844	Publication of **Synopsis of the Carboniferous Limestone Fossils of Ireland** (based on his work for Sir Richard Griffith).
1845	Geological Survey of Ireland established. McCoy hired as first field staff member. Surveyed and completed maps. Resigned September 1846.
1846	Publication of **Synopsis of the Silurian Fossils of Ireland** (based on his work for Sir Richard Griffith). In November invited by Adam Sedgwick to arrange the fossil collection of the Woodwardian Museum at Cambridge (worked on this project 1846-1854).
1847	Publication of **On the fossil botany and zoology of the rocks associated with the coal of Australia** in *Annals and Magazine of Natural History* (based on examination of fossils collected by Rev. W.B. Clarke and sent to Sedgwick).
1849	Appointed Professor of Mineralogy and Geology at Queen's College, Belfast. Continued work with Sedgwick during vacations.
1852	Elected Fellow of the Geological Society of London.
1854	Appointed Professor of Natural Science at the University of Melbourne (lifelong tenure). Publication of **Contributions to British Palaeontology** (reprint of 28 papers from *Annals and Magazine of Natural History*). Arrived in Victoria December 1854.
1855	Publication of **Synopsis of the British Palaeozoic Rocks and Fossils** (McCoy's major work). University of Melbourne officially opened. McCoy lectured in a wide range of subjects including chemistry, botany, mineralogy, comparative anatomy, systematic zoology, geology and palaeontology.

1856	Appointed Palaeontologist to the Geological Survey of Victoria. Moved National Museum of Victoria collection to University of Melbourne. 'System Garden' laid out in north-west corner of university grounds. Chairman of Royal Commission on the Victorian Goldfields.
1858	Formally appointed Director of the National Museum. Appointed to Victorian Board of Science.
1861	Vice-President of the Royal Society of Victoria. Acclimatisation Society established – McCoy and Frederick von Mueller Vice-Presidents. Publication of **Note on the ancient and recent natural history of Victoria** in Catalogue of the Victorian Exhibition – the first general account of palaeontology and zoology in Victoria.
1864	President of the Royal Society of Victoria.
1867	Publication of **On the recent zoology and palaeontology of Victoria** in *Annals and Magazine of Natural History* (included the first detailed list of Victorian birds).
1869	Public lecture **The order of creation**. Began publication of a series of popular articles on Victorian and Australian natural history in the *Australasian* under the pseudonym 'Microzoon' (from 1869-1871).
1870	Public lecture **The plan of creation**. Vice-President of the Royal Society of Victoria.
1874	First part of **Prodromus of the Palaeontology of Victoria** published (work on it actually started in 1858; published serially; publication ceased with seventh decade 1882).
1878	Publication of **Prodromus of the Zoology of Victoria** (in twenty parts with 200 coloured plates; published serially 1878-1890).
1879	Awarded Murchison Medal from Geological Society of London.
1880	Elected Fellow of the Royal Society of London. Invited to be First President of the Field Naturalists Club of Victoria (President for three years 1880-1883).
1880s and 1890s	Many honours conferred upon him including a knighthood (KCMG) in 1891. Now regarded by many as Australasia's most distinguished scientist. Honourary member of many British and foreign learned societies. Royal honours from Italy and Austria. Received D.Sc. from Cambridge 1886 (one of the first granted). McCoy's health deteriorated in 1890s – protracted bouts of bronchial illness. Wife died 1886, son died 1887, daughter died 1891.
1899	Died 13 May. Buried in the Brighton Cemetery, Melbourne.

Geological Time Scale

(a)	(b) ERA	PERIOD	EPOCH	Mill yrs ago	CHARACTERISTIC LIFE
Tertiary	Cenozoic	Quaternary	Recent	<10000 yrs	Man
			Pleistocene	1.8	
		Tertiary	Pliocene	5	Great variety of mammals
			Miocene	24	Flowering plants. Ancestral dogs and bears
			Oligocene	34	Ancestral pigs and apes
			Eocene	55	Ancestral horses, cattle, elephants
			Palaeocene	65	
Secondary	Mesozoic	Cretaceous		141	Extinction of dinosaurs and ammonities. Mammals and flowering plants slowly appear
		Jurassic		205	Dinosaures and ammonites abundant. Birds and mammals appear
		Triassic		251	Flying reptiles and dinosaurs appear. First modern corals
	Palaeozoic	Permian		298	Rise of reptiles and amphibians Conifers and beetles
		Carboniferous		354	Coal forests (North Hem.) First reptiles and winged insects
		Devonian		410	First amphibians and ammonities. Earliest trees and spiders. Rise of fishes
Transition		Silurian		434	First spore-bearing land plants Earliest known coral reefs
		Ordovician		490	First fish-like vertebrates. Trilobites and grapolites abundant
		Cambrian		545	Abundant fossils first appeart (trilobites, graptolites, brachiopods, molluscs, crinoids, radiolaria and foraminifera)
Primitive, or Primary	Proterozoic			2500	Scanty remains of primitive invertebrates: sponges, worms algae, bacteria
	Archaean			4600	Rare algae and bacteria back to at least 3400 million years

Geological strata classifications: (a) classification used in Britain in the 1820s (Secord, J.A. (1986). 'Controversy in Victorian Geology: The Cambrian-Silurian Dispute'. Princeton University Press: Princeton.) ; (b) current Australian classification (after Australian Geological Survey Organisation 1996).

Sir Frederick McCoy FRS – an Overview

Malcolm Carkeek[1]

When Frederick McCoy arrived in Melbourne late in 1854 to take up the foundation chair of Natural Science in the University of Melbourne he was plain Mr McCoy, without tertiary qualifications or honours, but already a Fellow of the Geological Society, London. At his death in 1899 he was Professor Sir Frederick McCoy, Knight Commander of St Michael and St George – the first professor of an Australian university to be knighted; Fellow of the Royal Society; holder of the Geological Society's Murchison Medal; Doctor of Science *honoris causa* (Cambridge) – the first to receive this newly created honour; Honorary Member of the Cambridge Philosophical Society – limited to 30 British citizens, the cream of the Empire's scientists; Chevalier of the Royal Order of the Crown of Italy; recipient of the Emperor of Austria's Great Gold Medal for Arts and Sciences, etc, etc, etc. He still held his professorship and had been foundation Director of the National Museum of Victoria since 1857. The recognition and the honours were the result of four decades of relentless drive by McCoy to create a museum that fulfilled the public role he perceived for it. In the late nineteenth century the National Museum of Victoria was recognised internationally as one of the world's great natural history museums. This status was achieved almost entirely by the unremitting determination, vision and passion of one man, against an array of opposing forces that would have eventually ground down and crushed a man not so possessed. As with many who make their mark, McCoy was a man of great enabling talents, dogged by a number of disabling characteristics.

In 1853, the newly established University of Melbourne was seeking to fill four chairs. One of a long and somewhat demanding list of criteria provided by the university to the selection panel in London was that the professorial candidates had to be graduates of one of the major universities of Great Britain. From a field of over ninety applicants, the panel, headed by Sir John Herschel the noted astronomer, chose three graduates well-recognised in their discipline, and Frederick McCoy who, although he did not satisfy the degree criterion, was so outstanding in his field that he was selected notwithstanding. McCoy was not without academic recognition; he was at the time Professor of Geology and Mineralogy in Queen's College, Belfast and was recognised in Great Britain as one of its leading palaeontologists. How he reached this position by his early thirties is explained in Tom Darragh's meticulous contribution. Shortly before leaving for Australia, McCoy had published the definitive work on the Palaeozoic rocks and fossils of Great Britain and was in the limelight in scientific circles for providing the palaeontological evidence that was instrumental in resolving the great Silurian/Cambrian controversy. This and McCoy's other contributions to stratigraphical palaeontology are covered in detail in Doug McCann's paper.

As amply demonstrated in Ian Wilkinson's paper, McCoy did not make his mark as one of the University's really great teachers, particularly in his later years. Considering everything else he was involved in, it is surprising that he ever got around to teaching at all. He was constantly at loggerheads with the Building Committee, mostly in regard to the National Museum; indeed one could add: the Chancellor, the Vice-Chancellor, the Registrar, the Professorial Board and anyone else who sought to thwart him in anything that he considered to be for the well-being or advancement of any enterprise for which he was responsible or closely involved.

McCoy was a convergent thinker, saw things in black and white, was obsessive about detail and was unable to appreciate that not everyone's thought processes are governed by logic, and hence he was often

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intolerant of other opinions. Basically, he was a fairly typical scientist. As Scott (1936) said of McCoy,

> His meticulousness was often trying to the University Council, and there was rarely a meeting of that body at which 'Letter from Professor McCoy' did not figure on the Agenda. Sometimes there were several letters from him, all pressing for something to be done.

McCoy would present a cogently argued case in support of some demonstrably valuable and justifiable plan, only to be knocked back with 'we can't afford it'. To a man of science this was no answer at all and he would persist, sometimes for years, until he got what he wanted.

Arguably, McCoy's major achievement for the University was the systematic Botanic Garden; and this is perhaps a good example of his relationship and interaction with others in the University community. From a faltering start in 1856, the garden grew under McCoy's watchful and caring eye through the sixties, the latter part of which were probably the peak of the garden's development and use, with two gardeners, heated glasshouses and all totally under the control of its founder. The seventies brought much disputation about staff numbers, their salaries and funds for specimens and running expenses. Money was always in short supply and the garden suffered in consequence. McCoy's constant importuning on behalf of his beloved garden met with little positive response; rather, he was more likely to be told by the Building Committee 'The wants of the general grounds at present are more urgent than is the necessity for propagating exotic plants which require artificial heat approaching that of the tropics!'. McCoy cuttingly referred to the former as 'pleasure gardens'. Finally, in 1880, the Council set up a committee to investigate the condition and management of the Botanic Garden. This committee recommended that the garden be removed from the control of McCoy and handed over to the Head Gardener – he of the 'pleasure gardens'. McCoy came out fighting, and replied that at the time of the inspection in Spring, the weeds were at their height and the one gardener was temporarily otherwise occupied; plants had died over the last twenty years and no money had been forthcoming to replace them, and at least the labels gave some indication as to what might have been there, had the garden been properly supported. Despite a strongly supported student petition to the Council calling on it to not remove McCoy from his curatorial role, control of the Botanic Garden passed to the Head Gardener, a man with whom McCoy had often clashed. The garden was allowed to deteriorate and its value as a teaching adjunct greatly diminished until it was eventually subsumed in the general gardens. Fighting against parsimony and disinterest, McCoy held the garden together for nearly 25 years, but lost in the end. Gwen Pascoe's paper describes the establishment and layout of the garden, and expands on McCoy's problems in managing it.

It was the Surveyor General, Captain Andrew Clarke RE, who first recognised the value, and was the driving force behind the establishment, of a public museum for the education and instruction of Victorians. Clarke had been Secretary to Governor Denison in Tasmania when a public museum was set up there under the aegis of the Royal Society of Van Dieman's Land. Clarke took up his duties in Victoria in May 1853, and in the following September the Legislative Council voted 36 to 7 that the Estimates of the following year include a sum for the establishment of a Museum of Natural History. The 1854 Budget included a sum of £2,000 towards the establishment of such a museum, and a similar sum for a Museum of Economic Geology. Both were placed under the control of Clarke, and he found two rooms above the Assay Office to house them. The collection grew rapidly under the curatorship of the Government Zoologist, William Blandowski. But, between mid-1855 and the end of 1856, the whole collection was transferred to the University and placed in the care of Professor McCoy. At the time there was much opposition, much confusion and not a little dissembling regarding this operation. Some source material from the period has been influential in the painting of an unfair image of McCoy in more recent times.

In *Redmond Barry*, Ann Galbally (1995), in referring to the movement of the national collection to the University, states,

'McCoy saw his chance, and in another example of Irish energy organised to "borrow" the collections for an exhibition at the University. They were never returned in his lifetime.' She later claims that Barry 'decided not to oppose McCoy's commandeering of the Museum of Natural History'. Ann Moyal (1986), a respected historian of Australian science, says of this event,

> ... at Melbourne University ... McCoy built up an impressive economic and mining museum which attracted great attention from the public. Fired by this success, and already negotiating with the governor of Victoria on the housing of the national collection, McCoy, in the summer of 1856, unceremoniously carried off the natural history collection, despite protests from the Philosophical Society.

She calls this 'an act of brigandage'. McCoy himself best answers these charges in a letter dated 28 June 1856 to Redmond Barry in his capacity as Chancellor of the University. It is a key document and worth quoting extensively.

> About a year ago His Excellency Sir Charles Hotham having determined to omit the Colonial Natural History grants from the estimates and an announcement having appeared in the papers that the Survey Museum was to be broken up, I waited upon the authorities and having represented the advantages to the community of continuing the collections and ascertaining exactly what natural objects were to be found in the Colony, I suggested that the economic difficulties in the way (such as the necessity for building a separate museum, purchasing the large number of cases required, paying attendants, etc.) might be obviated by placing the collections in the charge of the University; where also the necessary scientific books and specimens of other countries for comparison would be at hand to facilitate the classification of the specimens, and where they could be safely deposited, arranged and be freely open to the public.
>
> The Colonial Secretary thereupon forwarded at His Excellency's desire the letter dated 10th July 1855 enclosing a memorandum, dated 29th June 1855, of my proposition and desiring the opinion of the Council of the University thereon.
>
> To this the Council replied by letter dated Sept. 15th, expressing their willingness to take charge of these collections, but a paragraph having been introduced to the effect that money should first be furnished to build a Museum for them, His Excellency was obliged to reply, by a letter dated Sept. 25, that he could not sanction the arrangement on such terms till the money was voted by the Legislature. Immediately however on the Council writing, by letter dated Oct. 2nd, that they would unconditionally accept the custody of the collection, His Excellency forwarded to them a letter of thanks, dated Oct. 16th and promising to communicate directly on the Surveyor General's return.
>
> Accordingly, on the arrival of the Surveyor General that officer came to the University to ascertain what means we had for carrying out the arrangement; and, having carefully inspected the rooms which we then had ready for temporary accommodation, and examined the plans and drawings of the Museum we then proposed to build, with the necessary fittings, glass cases etc. he expressed himself perfectly satisfied and **gave me a definite promise** that he would order the collections to be sent up at once.
>
> Finally, when another member of the Executive (the Honorable the Commissioner of Trade & Customs) asked the Legislative Council to agree to the vote for building the north side of the University he distinctly announced that the Colonial Natural History Collection **had been transferred to the University** and that this small vote would save the country the great expense of providing separate accommodation for them.
>
> The Botanical specimens have been partially delivered and the whole of the Geological collection made by Mr. Selwyn have arrived and are rapidly being classified and made useful at the Department ...

I have read each of the documents to which McCoy refers, and they all agree with what he says. This was not a brigand commandeering that to which he had no right, but rather the orderly transfer of the collection, as agreed and arranged between the Government and the Council of the University. When the transfer of the national collection from the Assay Office to the University was well under way, the

death of Governor Hotham and the installation of a more sympathetic, if temporary, ear in the form of Major General Macarthur gave the Philosophical Institute the opportunity to perhaps reverse the decision with which it strongly disagreed. It petitioned the Acting Governor to relocate the national collection in the Public Library basement, prompting the Colonial Secretary to ask the University if it was prepared to continue to be responsible for the national collection and the Trustees of the Public Library if they were prepared to assume responsibility for it. On behalf of the University, the ubiquitous Redmond Barry replied, *Yes*; and on behalf of the Trustees, he replied, *No*. On hearing this, the Philosophical Institute organised a public protest meeting on 26 July 1856 – recall that McCoy's letter was dated 28 June. Not surprisingly, those who were moved to attend voted overwhelmingly to have the National Museum in the city. When the next shipment of specimens from the Assay Office to the University happened a few days later, the Philosophical Institute and the press had a field day accusing McCoy of all sorts of malfeasance. *The Argus* fulminated and *Melbourne Punch* lampooned him in cartoon and doggerel; and writers have been perpetuating this myth ever since.

The establishment of the museum in the University gave McCoy the opportunity to once again do what his previous activities showed he most enjoyed; building up and directing a natural history museum – and this he set about doing with considerable skill, zeal and tenacity. Soon some funds were forthcoming from the Government and additional space added to the University buildings to house the National Museum. Over the next six years McCoy avidly acquired specimens from both the collectings of the ongoing Geological Survey of Victoria and through overseas agents, but only 'those of the highest quality'. Anthea Fleming's paper on McCoy's correspondence with John Gould relating to the acquisition of bird collections for the museum clearly illustrates the problems McCoy had in financing acquisitions in general and the extent to which he was prepared to circumvent normal fiscal restraints to advance his beloved museum. McCoy soon ran out of display and storage space in the museum and again appealed to the Government, who after negotiations with the University Council built one half of a planned National Museum building within the University grounds. It was never to be completed. The development of the museum under McCoy's leadership is explored and detailed in Carolyn Rasmussen's paper.

The University had initially welcomed the housing of the national collection on its campus, albeit on a temporary basis, and the Council gave unanimous approval for its extension. By 1865 the University's attitude to hosting the National Museum had changed considerably; it saw this nestling as a rapidly growing cuckoo threatening its own fledgling museum. From time to time McCoy was required to list recent acquisitions of the University Museum. As the University was always running on a reduced budget, little money was made available to McCoy to purchase specimens, hence the collection grew slowly and mostly by donations. McCoy had a somewhat perverse sense of humour; on one occasion he reported, po-faced, that there had been few additions during the year, with the chief of these being:

- A bottle of slugs, supposed to have been vomited up by a man (donated by the Vice-Chancellor);
- A bottle of water from Tarrangower (also donated by the Vice-Chancellor);
- Three birds' nests and the beak of an albatross;
- A piece of wood from the Holy Land;
- A small crawfish from the Yarra;
- A small box of insects;
- Three bones (unidentified).

In 1869 the government placed the Public Library, the Museums and the National Gallery under the control of a board of trustees. McCoy, who had held his directorship of the Museum through his position of State Palaeontologist and was thus answerable only to the Chief Secretary, now had 15 'masters', including Redmond Barry who was the Board's first President. As well as a wig, Barry wore other hats: in regard to the National Museum he was positioned uneasily between being President of the Trustees vested with its control and Chancellor of the University.

He and McCoy were often in conflict over the Museum. In 1856, Barry the Chancellor was interested in acquiring the Museum for the University, while Barry the Museum Trustee wanted the available space in the Public Library building for an Art Gallery. As time went on and more space became available at the Public Library, Chancellor Barry, perhaps weary of his regular confrontations with McCoy, yielded to Trustee Barry and pressed for a relocation of the Museum. For reasons yet to be established, Barry, the mover and shaker, was not wholly successful. The Trustees wished to have the whole of the Museum moved to the Library site, but the Act incorporating the Library, Gallery and Museums specifically forbad the removal of the Natural History Museum from the University; so they appointed a Sectional Committee to control the operation of the Museum and its Director. The general attitude of the Trustees may be gauged from the fact that none on this committee had any background in science. The committee lost no time in putting its stamp on the Museum. Declaring its intention that the National Museum should be 'a collection illustrative of Zoology and Palaeontology' it ordered that the mineralogy collection and the mining and agricultural models that McCoy had so assiduously collected from Europe were to be removed to the new Science and Technology Museum, situated in the Public Library building, and under the control of another curator. McCoy fought vigorously but in vain, because the Government sanctioned the move. Ostensibly, the action was to relieve the overcrowding at the National Museum and make the models more readily available to the public, but the setting of the battle lines on who was master and who servant must have also played a part. In 1870, the Committee paid tribute in its first annual report to 'the zeal and perseverance of the learned Director, Professor McCoy.' In 1876, they observed pompously 'The general conduct of the Museum has during the year met with the approval of the Committee.'

As explained in Doug McCann's stratigraphy paper, McCoy was at home in the laboratory and the office rather than as a collector in the field, and it was there, as Director of the Museum and State Palaeontologist, that he made his major contribution. Many of the local specimens collected by the Geological Survey and amateur collectors were identified and named by McCoy – similar to the work he had done with the Woodwardian collection at Cambridge University. While his work ranged widely, the following papers highlight some of the areas in which he contributed significantly: John Seebeck and Robert Warneke, 'McCoy's Mammals'; Alan Yen *et al.*, '*Prodromus of Zoology*'; Philip Bock, 'Bryozoa'; Noel Schleiger, 'Graptolites'; Leigh Ahern, 'A Bite from the Past'; Neil Archbold, 'Brachiopods'; Mark Warne, 'Bairdia'; Adrian Hell, 'Ichthyosaur'; and Bernard Mace, '*Thylacoleo*'.

As you read the annual reports of the Museum Committee with their Appendix A – Director's Report, between the years 1870 and 1899, the profile of a resolutely determined man of indomitable spirit emerges. Year after year for 29 years McCoy reported that there was a desperate shortage of public and operational space in the museum that caused such overcrowding as to make viewing of the exhibits difficult, but the number of visitors continued to increase, as did the number of specimens received, prepared, identified, catalogued and arranged. Each year there was an ever-optimistic appeal for capital funds to complete the other half of the Museum building. This plea was invariably matched by that of the Committee, but they sought funds to relocate the Museum to an extended Public Library site. Finally, in 1876 the Government placed upon the vote for Public Works, £2,000 for '... additions to the National Museum.' The Committee decided 'that it is not desirable to expend any more money for this purpose on the University Grounds, but that a suitable building be erected on the site vested in the Trustees'. None of this money actually eventuated and over the next 20 years governments came and went; some voting funds for the Museum, but none carrying the work through. Even during the booming 1880s the Museum's operating funds were steadily eroded to a point where creditors and even staff were not being paid and the purchase of specimens from over-

seas was out of the question.

These were not happy times for McCoy. Quite apart from the difficulties with which he had to contend at the Museum, the death of his wife, son and daughter within five years of each other; mounting financial problems (mostly caused by paying for Museum acquisitions from his own pocket rather than lose an opportunity to gain some important specimen); and steadily deteriorating health, left him bruised and perhaps a little bowed. He wrote to Baron von Mueller in 1891:

> I am still so weak, & get my strength back so slowly that I am quite out of spirits and patience. Yesterday after my second lecture I was so exhausted that I had to go and lie down before I could go home. Each day however I am a little better & hope soon to be well enough to tackle my arrears of work and return thanks to all the Kind enquiries during my nearly three months mostly in bed. My medical attendant protests against my return to work and lecturing.

While this was a time of recovered amity, 30 years earlier McCoy and Mueller found themselves on opposite sides in a tussle between colonial and imperial science in the form of the Cranbourne Meteorites, the full story of which is given in Sara Maroske's paper.

It is easily forgotten that McCoy held down two full-time jobs throughout the 43 years from 1856 to his death at the age of 77, and served on numerous governmental advisory bodies during this period. He was an active member and office-holder of the Royal Society of Victoria, a regular contributor to local and international scientific journals, provided an anonymous contribution on natural history topics (see McCann, Microzoon) and maintained a busy correspondence with fellow practitioners around the world. At his death the museum contained over half a million specimens; and while a substantial number came as established collections, the majority were identified, catalogued and arranged by McCoy himself over the four decades the Museum was in his care.

If the Trustees, the University and the Government found McCoy to be a thorn in their collective side, the rest of the world was more generous in its recognition. Australia had a unique native flora and fauna that was attractive to museums around the world. McCoy traded far and wide, and through the national museums of many countries gained important contacts and an international reputation as a natural history scientist. Civil, academic and professional honours followed.

While McCoy is particularly known for his role at the Museum and the University, there were other organisations in which he was involved and/or recognised. In 1935, at the suggestion of the Vice-Chancellor of Melbourne University, a society for the study of field investigation and research was set up and named for McCoy, honouring the foundation professor of Natural Science. The society's 60+ year history is reviewed in David Ashton's paper 'The History of the McCoy Society'. It seems that McCoy's name carried some cachet. As Sheila Houghton reveals in her paper 'Frederick McCoy and the FNCV', McCoy, despite having been elected foundation President, limited his participation in the Club's activities over the three years he held the position to giving the Presidential Address at the annual Conversazione. He was somewhat more involved in the Acclimatisation Society of Victoria. In 1862, McCoy made a seminal address to the Society. In it he sounded a sober, cautionary note against a growing enthusiasm for attempting to bring fauna from all over the globe to be acclimatised. He stressed that only animals from regions of similar climate should be considered and condemned the importation of 'exotics'. On a lighter note he spoke of his own sadness at not being able to hear the song of European birds in an alien environment and he strongly promoted their import as an anodyne for homesickness. The good sense of the former has been ignored and the humanness of the latter has been ridiculed. Linden Gillbank's paper traces the history of the Zoological Society and the Acclimatisation Society and the degree to which McCoy contributed to them.

All of about a dozen articles I have read focus their condemnation of the Acclimatisation Society on McCoy and a knee-jerk reaction might be to believe that he was personally responsible for the introduction into Australia of everything from rabbits to cane-toads. When you carefully

evaluate all this material you realise that McCoy was, in fact, a fairly inconsequential player in the whole imbroglio. One explanation of this apparent anomaly is that McCoy has been made a lightning rod for all the Jovian bolts that those blessed with 20/20 hindsight so enjoy casting. When you write about events that happened a century or more ago there is a limited amount of paper on which to draw. McCoy was a great one for producing paper; he corresponded widely, he was a member of all the learned societies in the colony, he wrote letters to the papers, he lectured on controversial subjects – that were then reported in the papers; he had an opinion on everything and was not afraid to express it – he provides much quotable material. This results in his appearing larger than life and to having a higher profile in a number of events and issues than he in fact deserves – and this applies just as much to his accredited successes as to his perceived failures. It has been said that he who never makes a decision or takes a position, never makes a mistake; the obvious corollary is that the more decisions and positions you take the higher your rate of mistakes is likely to be. McCoy was never loath to lay it on the line and consequently he made some really big blunders that, had they been acted on, would have had significant economic consequences for the colonies.

As everyone knows, in the early 1850s there was a gold rush in Victoria. But as quickly as they were discovered, the alluvial deposits were panned out and more sophisticated and deeper-seeking methods were required. In 1856 a Royal Commission was set up under the chairmanship of Professor McCoy to investigate the long-term potential of gold mining in Victoria. The resulting report was at once a disappointment and a puzzle to the mining fraternity. Whilst opposing him on the Carradoc beds, McCoy deferred to Murchison in the latter's contention that gold veins in quartz were at their richest nearest the surface and diminished with depth. As more and more reefs were traced down and down – some to a depth of half a mile at Bendigo and still yielding payable gold, McCoy became something of a laughing stock. Serle (1963) says, 'McCoy probably more than any man created or confirmed the Australian legend of the "impractical academic"'. While this is perhaps a little harsh, McCoy certainly did not cover himself in glory in this area, nor in his dispute with Rev. W.B. Clarke over the age of the NSW coalfields.

Clarke, another of Adam Sedgwick's students, might rightly be called the father of Australian geology. He was based in NSW and was the major influence in defining likely areas for coal exploration. While Roger Pierson clearly explains the whole controversy in his paper by presenting the geological and palaeontological evidence, the essentials are that McCoy and Clarke disputed the age of some of the coalfields in NSW, based on their fossil content. If McCoy were right, the potential for coal discoveries in NSW would be substantially lower than if Clarke were right, with the viability of a major economic resource at question. McCoy based and held his position on his examination of specimens that Clarke had sent to Cambridge while McCoy was working there. McCoy assessed them in terms of European geology, while Clarke was on the ground in Australia. Whilst the dispute raged for twenty years, McCoy made no attempt to travel up from Melbourne to Maitland to see for himself, despite repeated invitations and challenges by Clarke to do so. He certainly was an intractable reactionary!

Because McCoy did not wholeheartedly accept Darwin's theories of evolution he has been dismissively labelled a 'creationist'; a term that has pejorative connotations for many. It would be misleading to view him in this context. While ultimately deferring to a 'Divine Blueprint', he presented in two public lectures circa 1870 a carefully reasoned scientific position opposing Darwin, based on available geological and palaeontological evidence and firmly embedded in the prevailing scientific paradigm. He was not persuaded by a new and questionable hypothesis that challenged the perceived wisdom of Science, Society and Religion. Today, most would consider him wrong-headed. But his was not the wrong-headedness of dogmatic theism; rather McCoy was perhaps something of a deist. It was more a case of McCoy's science informing his religion, rather than his religion confounding his science. Darwin's

theories are best observed at work in more recent times, geologically speaking. The fossil record today does not show a slow but steady transmutation from one species to another; and in McCoy's day much less was known, much less discovered. Indeed, today we still see large gaps in the fossil record; transition species are few and far between. Stephen Jay Gould (Eldredge and Gould 1972), a respected American palaeontologist, hypothesises the uneven fossil record in terms of 'punctuated equilibria' – long periods of genetic stability interrupted by brief flurries of major mutation. Echoes from McCoy's lectures sound curiously contemporary.

> ... The whole scheme of nature is not a continuous unbroken cord or chain of slight development, as the progressive development theory would require; but that at the point of change from every one of these subkingdoms to another you find a total change of plan - a totally new mode of construction for all the essential characteristics of the creature.

Barry Butcher's paper on McCoy and Darwinism looks at the issue in the social and religious context of the time and – both generally and specifically – at McCoy's position in it. Wayne Gerdtz's paper on *Sarcophilus harrisii* provides an interesting insight into how McCoy's attitude to evolutionism impacted on the practice of his science.

Presently, not a great deal is known of McCoy's personal life. He was the second son of Simon Henry McCoy (c. 1795-1875) and Bridget (surname not known; c. 1799-1876). They had at least three children: a son of unknown name, Frederick and Agnes (c. 1826-1901). Simon was a prominent medical practitioner in Dublin, a Licentiate of the Royal College of Surgeons from 1828 and Professor of Materia Medica, Medical Jurisprudence and Toxicology in Queen's College, Galway, from 1849 (the same year in which his son Frederick became a professor in Queen's College, Belfast). McCoy was expected to follow in his father's professional footsteps but, after completing the theoretical work for his medical degree and being too young to practise, he pursued his passion for natural science, did not complete the requisite practical experience and thus was not admitted to the degree – see also Tom Darragh's paper. Medicine's loss was palaeontology's gain.

In 1842 McCoy married Anna Maria Harrison (c. 1819-1886), daughter of Thomas Harrison, Attorney, and Eliza Coonan. To Anna were born five children, three of whom died in infancy. Frederick Henry (1843-1887) graduated in Law from the University of Melbourne in 1868 and migrated to New Zealand where he set up practice in 1870 as a barrister and solicitor in the country town of Lawrence. He married Mary Ann Thompson (1852-1938) in 1870 and they had eight children. Emily Mary (1842-1891), unmarried, lived in the parental home all her life, probably housekeeping for her father after her mother's death.

The McCoys were members of what might be called the 'intellectual aristocracy' of Melbourne; McCoy was a member of the Melbourne Club and a Justice of the Peace, and one gets an occasional glimpse of their social life through the diary entries of their contemporaries. McCoy was born a Roman Catholic and was buried in Brighton Cemetery according to the rites of the Church of England. Whether this was a 'Via Damascus' conversion or a pragmatic update to his *curriculum vitae* in a Protestant England is unknown, but Rev. Sedgwick, a minister of the Church of England, and mentor of the young Frederick, somewhat dramatically averred in a letter supporting McCoy's application for the Melbourne University post that: '... McCoy was brought up a Papist but he was a good truth-loving Catholic, and never a Gadarean swine – He is now a conscientious member of the English Church; ...' The McCoy children were raised and died in the Church of England. However, in his later years McCoy was much involved with Xavier College, and at his death a Roman Catholic priest claimed that he had made a deathbed recantation, but this was strongly denied by a grandson who was present at the time. The truth of the matter will probably remain unresolved.

Shortly after his wife's death in 1886, McCoy, on six month's sabbatical leave and accompanied by his daughter, visited England, to be invested as a Companion of St Michael and St George and to look up

old friends, Turkey – a geologist in search of the Ark? and probably a number of other countries. It was the only time he left Australia. While initially occupying one of the professorial houses on the university campus for some years, Frederick, Anna and Emily spent most of their lives in their South Road, Brighton home, *Maritima* – which is now part of Xavier College. In McCoy's papers there are a couple of land transfer and ownership documents, but neither bears his name. What is known is that he did own at least one other property, as related in Doug McCann's paper 'Frederick McCoy's Mount Macedon Property'.

While we know he died on 13 May 1899, in the absence of a birth certificate there is some controversy in Australia about McCoy's birth date. All direct or derived sources from Great Britain unequivocally state 1823, as do most Australian sources, including *The Age* obituary. The alternative date of 1817, used in the Australian Dictionary of Biography, appears to have originated from a single source – the obituary in *The Argus*. Australian sources that give 1817 as the date justify it by pointing out that McCoy had a scientific paper published in the *Magazine of Natural History* in 1838, making him 15 at the time, if born in 1823. See Darragh's paper for further details. Drawing on a number of sources, I have concluded that McCoy was most likely to have been born in 1822 or perhaps 1821. 1821/22 will appear in McCoy's entry in the new edition of the 'Dictionary of National Biography' (due 2004). McCoy's name is found in various documents as either McCoy or M'Coy. Neil Archbold takes a brief look at this issue.

One of the most fruitful areas for further research into McCoy would perhaps be to resolve how it was that he managed to retain control of the National Museum and keep it at the University for 43 years against the wishes of powerful forces; through 26 state governments, numerous university councillors and museum trustees; and yet within six months of his death, the whole of the National Museum collection was relocated in downtown Swanston Street, where it shared cramped premises with the State Library and the National Gallery of Victoria, to the detriment of all.

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Editors' Acknowledgements

A special issue of *The Victorian Naturalist* was first proposed in July 1999 to commemorate the centenary of the death of Sir Frederick McCoy, the first President of The Field Naturalists Club of Victoria. Work started in March 2000, but because of the interest from many authors and the large amount of material we received, it soon became apparent that the issue would be much larger than anticipated (ultimately requiring two issues) and take much longer to prepare. Thanks are due to many people who assisted us – Virgil Hubregtse and Michael McBain diligently proof read all the manuscripts, and members of the editorial committee (Tom May, John Seebeck, Ian Endersby and Ian Mansergh) provided valuable advice. Charles Leski Auctions digitally photographed many of the images contained in these issues and Steve Kitto of Brown Prior Anderson Pty Ltd (our printers) also provided technical assistance. Permission to reproduce pictures was kindly granted by the State Library of Victoria, Museum Victoria, the University of Melbourne Archives and Art Collection and Peter Schouten.

John Seebeck (NRE) and Tom Darragh (Museum Victoria) helped with planning in the early stages. Frank Job, head librarian at Museum Victoria provided access to McCoy's original correspondence and Wayne Longmore, also at Museum Victoria located some of the bird specimens purchased by McCoy for us to photograph.

Dr Doug McCann first proposed the idea of a special issue on McCoy, provided much assistance in planning the issue and commissioned many of the writers. Professor Neil Archbold of Deakin University suggested, and provided the funding for, the colour section of Part Two. We are most appreciative and thank them both.

Frederick McCoy: the Irish Years

Thomas A. Darragh[1]

Frederick McCoy was Australia's first resident palaeontologist and until the arrival in Adelaide in 1875 of Professor Ralph Tate (1840-1901) its only professional palaeontologist. Of McCoy's education, we know nothing except some evidence to suggest he may have attended a school run by the Jesuits in Dublin (Dening and Kennedy 1993). Since his father, Simon, was a physician, it is not unreasonable to suspect that his father may have had some influence in developing an interest in natural history. Whatever his education, he must have been something of a child prodigy, because he published his first paper, on birds, 'Remarks on Mr Eyton's arrangement of the Gulls' in the *Magazine of Natural History* in 1838, when he would have been about 14 or 15, and also gave a lecture on the orders of birds to the fourth meeting of the Natural History Society of Dublin on 16 April 1838. McCoy stated that it was intended he follow his father's profession, and being a lonely child, he spent much of his time studying (Anon 1891). It is alleged that he attended medical courses in Dublin, perhaps conducted by his father, but was too young to enrol formally in a course. Despite this, in November 1839 he gave two lectures on anatomy to the Peter Street Anatomical School, run by his father. That same year he joined the Geological Society of Dublin and was appointed assistant to Dr John Scouler (1804-1871), one of the two secretaries of the Society, to assist in arranging the fossil collections in the Society's Museum (Griffith 1841). Scouler, an eminent naturalist, was Professor of geology, zoology and botany at the Royal Dublin Society and must also have been an important influence on McCoy.

In 1839 McCoy published his first description of a fossil, a Carboniferous ostracod *Entomoconchus scouleri*, in a paper entitled 'On a new genus of Entomostraca from the Mountain Limestone' in the *Journal of the Geological Society of Dublin* (McCoy 1839) (Fig. 1). He continued working at the Geological Society of Dublin into 1841 and also that year arranged the collection of Henry Charles Sirr for sale (McCoy 1841a, b). The appendix of the catalogue of organic remains of the Sirr collection contains descriptions of nine species of fossils (McCoy 1841a). His position with the Society was terminated in February 1842 for neglect of curatorial duties (Herries Davies 1983) and it has been alleged that his work was slipshod. His successor in this position was Thomas Oldham (1816-1878), who later was to quarrel with McCoy over fossil identifications and was certainly prejudiced against McCoy, as later events proved.

The catalogue of the Geological Society Museum, issued in 1841, has an appendix containing descriptions of new species of fossils. There is no author cited for this but McCoy is credited with the arrangement in the introduction to the catalogue and presumably he was the author (McCoy 1841c). He certainly listed it amongst his publications when applying for the Melbourne chair. Whilst McCoy was undertaking this work, he was also working as a palaeontologist for Richard Griffith (1784-1878), who had invited McCoy to determine the fossils collected by him and his staff of the Boundary Survey of Ireland. Griffith needed McCoy's information to determine ages for his Geological Map of Ireland, then in process of compilation. The results of this work were published in 1844 as *Synopsis of the Carboniferous Fossils of Ireland* and in 1846 as *Synopsis of the Silurian Fossils of Ireland*. McCoy was a talented natural history artist and undertook the necessary illustration in these monographs and his other publications himself. The publication of the two monographs was financed by Griffith, who, unfortunately for McCoy and later palaeontologists, 'suppressed ...

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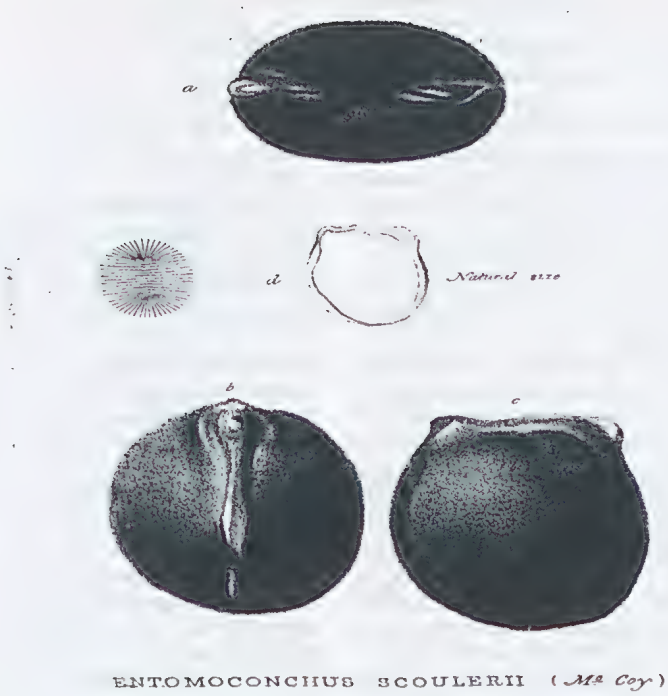

Fig. 1. Illustration from McCoy's first paper published on a fossil. 1839.

a great deal of McCoy's good work' by cutting out all the locality details of the fossils as a cost-saving measure (Sedgwick 1854). Possibly it was this work for Griffiths that left McCoy open to accusations of neglect of his duties to the Geological Society. It was while working at the Society in 1841 that McCoy first met Adam Sedgwick (1785-1873), Professor of Geology at Cambridge University, who was on a visit to Dublin. Sedgwick seems to have been impressed with the young McCoy, who was working on Richard Griffith's fossil fish at the time (Sedgwick 1854), and was later to play a very important role in McCoy's advancement.

In November 1842, McCoy applied for the position of Curator of the Museum of the Geological Society of London, in place of William Lonsdale. McCoy was one of nine candidates, including Edward Forbes (1815-1854), Edward Charlesworth (1813-1893), N.J. Larkin (1781-1855) and Thomas Oldham, who became well known names in geology (Hutton 1842). Forbes received the appointment. In 1843, McCoy married Anna Harrison and two children, Emily and Frederick Henry, were born soon after, so McCoy had need of more permanent employment to support his family.

Late in 1844 McCoy was in negotiation with the Royal Dublin Society concerning the arrangement and naming of its collection of recent and fossil specimens, but was not employed, possibly because of lack of funds (Griffith 1844). At this time discussions were also under way concerning the establishment of a geological survey for the whole of Ireland. Early in 1845, McCoy had been in touch with Henry James (1803-1877), who was to be the Local Director of the Survey and who seems to have been keen to have McCoy as palaeontologist (James 1845a). However, when the Geological Survey of Ireland was formally established, it was decided that all the fossils would be determined by Edward Forbes, who was then Palaeontologist to the Geological Survey of England and Wales. McCoy wrote on 22 March applying for a position on the Survey and on 22 May he was offered an

appointment as an Assistant Geologist by James, who advised that his 'assistance will be required principally in the field, and not as a fossilist' (James 1845b). The appointment was to be probationary for six months, with permanent employment subject to satisfactory performance. The pay was 10 shillings per day for a working week of six days. McCoy accepted the offer on 24 May and was sent to map an area in County Carlow (Herries Davies 1995). It is clear from surviving correspondence that James was pleased with McCoy's progress and that they got on well together. Even Henry De La Beche (1796-1855), Director General of the Geological Survey, was pleased with McCoy's work when shown one of McCoy's sections by James (James 1846).

Unfortunately for McCoy, James resigned his position in June 1846 and the new appointment as Local Director went to McCoy's enemy Thomas Oldham. McCoy's difficult position was well appreciated by James, who went so far as to inform De La Beche that he felt it advisable McCoy be transferred to England, but De La Beche did not treat the matter seriously and McCoy remained in Ireland. McCoy had feuded with Oldham at Geological Society meetings from at least June 1844 to as late as June 1846 over Oldham's comments on some of McCoy's determinations of Carboniferous fossils. Oldham took up his duties in July 1846 and it was not long before he was making complaints about the quality of McCoy's work. On 29 August 1846, he wrote to McCoy pointing out errors in his mapping. At first McCoy defended himself by stating that he was precluded from offering any explanations because Oldham had not given any particulars, but McCoy must have realised that Oldham would keep hounding him, so he resigned on 30 September 1846, on the grounds of 'the strong personal animosity he always exhibited towards me' (McCoy 1846). Some of McCoy's field sheets have survived and they show what could be regarded as slipshod work, but it should be borne in mind that the mapping was at a scale of six inches to the mile which does allow very precise mapping if the geologist is expected to map every detail he comes across. However, McCoy, as well as the other geologists, was probably inadequately briefed and James himself probably had no real idea of exactly what was required. How much of Oldham's criticisms of McCoy were due to real problems and how much to prejudice cannot be ascertained (Herries Davies 1995).

In July 1846, anticipating problems with Oldham, McCoy had tried unsuccessfully for other positions. Richard Griffith suggested McCoy seek a professorship at Cork and that he would speak to Robert Kane (1809-1890) of the Royal Dublin Society, who wrote to McCoy advising that he was glad McCoy had applied and would let him know if he heard anything (Griffith 1846; Kane 1846). Nothing came of this.

On the advice of Henry James, by now at Southampton, McCoy contacted Adam Sedgwick in Cambridge (McCoy 1846), who wrote in November 1846 that he could offer no permanent employment, but only what he had already intended to offer Joseph Beete Jukes, who instead had taken up a position with the Geological Survey. This was '100 £ from my own purse & I trusted that I might obtain another 100 £ from the University - and I thought he might be induced by this sum to take up his quarters here for one year arranging our Museum'. He then went on to say 'could you give me any notion of the sum which (and in the circumstances I have pointed out) would induce you to come for one year to Cambridge?' (Sedgwick 1846). McCoy accepted the offer, which eventually was extended for another two years.

McCoy's first contact with Australian fossils was in 1847, when he studied and published on a collection of fossils from the coalfields of New South Wales and Tasmania, sent to Cambridge by Rev. W.B. Clarke (1798-1878) (see Pierson *this issue*). McCoy determined, erroneously as it turned out, that these fossils were Mesozoic in age (McCoy 1847), a view he continued to hold when he came to Melbourne, and which strengthened in his mind when he examined fossils from Victoria that were truly Mesozoic. This view was the basis of a long dispute with Clarke about the age of the New South Wales and Victorian coalfields, in which

neither one could see the merits of the other's arguments (Vallance 1981).

During his time at Cambridge, McCoy attended lectures in Botany (1847), Chemistry, Medicine and Surgery (1848), but never completed a degree. Even as late as 1852 he intended to take out a medical degree, but he never finished the final subjects. It seems that more interesting activities prevented him. Despite this lack of formal qualifications, his experience and ability were such that he secured the appointment of Professor of Mineralogy & Geology at Queen's College, Belfast in August 1849 and he continued to work with Sedgwick during the University vacations.

The palaeontological results of this collaboration with Sedgwick were published in three parts from 1851 to 1855 in a large monograph, *A Systematic Description of the British Palaeozoic Fossils in the Geological Museum of the University of Cambridge* (Cambridge), but, apart from a 100 page introduction, Sedgwick's contribution never appeared. As well as his major works, McCoy published about 30 articles between 1845 and 1854 on a variety of subjects but mostly on Palaeozoic fossils (Anon 1899). Much of McCoy's palaeontological work was directed towards supporting Sedgwick's position in Sedgwick's great battle with Sir Roderick Murchison over the boundary between the Cambrian and the Silurian Systems (Secord 1986; see McCann *this issue*).

Because his salary at Belfast was only £200, McCoy was anxious to obtain more lucrative employment. In June 1851 and September 1852, he unsuccessfully offered his palaeontological services to the British Museum, and in November 1853, following Edward Forbes' appointment to Edinburgh University, McCoy unsuccessfully applied to succeed Forbes as Palaeontologist to the Geological Survey (McCoy 1851, 1852, 1853). In December 1852 he applied for the Vice-Presidentship of Queen's College, Galway. This position was to be held with the Chair of Zoology. Despite having excellent references, he was unsuccessful. Had he been appointed, McCoy would have joined his father who was already a professor there. In support of McCoy, Sedgwick (1852) wrote:

> For about five or six years he has been most intimately connected with Cambridge. During three years he entirely lived amongst us, and during the last two or three years he has spent a large portion of each year amongst us – carrying on, with almost incredible labour and perseverance, a great scientific work which he has now brought nearly to completion. He was originally destined for the medical profession, and he still I believe, purposes to take a medical degree, for which purpose he has attended a part of our Cambridge course and obtained a certificate to that effect. He is a man of liberal attainment, of cheerful gentlemanlike manners, and of a tolerant temper and disposition, which enable him to live on terms of familiar friendship with men who widely differ from him in opinion. Thus, altho' he is a Roman Catholic and conforming to the discipline of that church, he has gained the confidence and cordial goodwill of men of all parties in Cambridge. Of course I now speak of the University of Cambridge in which there are persons of very different and very strong opinions. I am absolutely certain that all the Members of the University, who had the pleasure of his acquaintance, will bear testimony to that which I am here asserting. No man can, I believe, lament more than himself, the intolerance and violence of the extreme religious parties in Ireland. I think this remark important, for of his great attainment as a naturalist and comparative anatomist there can be no doubt, and on these points he can appeal to his published works and obtain most ample testimonials. I believe him to be one of the very best palaeontologists in Europe. No one of my friends (and I have been the Cambridge Professor of Geology for 34 years) has so large an historical knowledge of foreign works on Palaeontology, and no one of my friends has for the last 16 or 17 years, worked so hard with hands and head as he has done, among all parts of the animal kingdom revealed to us in the old world.

This high opinion of McCoy was by no means confined to an old employer and collaborator, but was also held by others. It was probably the influence of Sedgwick, coupled with the anti-Catholic prejudice that McCoy constantly experienced, that caused McCoy to convert from Roman

Catholicism to Anglicanism about May 1854. Sedgwick remained a close friend until the latter's death in 1873.

By 1854 McCoy was regarded as one of the leading general palaeontologists in England, specialising in the Palaeozoic. With this background, yet lacking the stipulated degree of one of the five great British universities, he applied for the position of Professor of Natural Science in the newly established University of Melbourne in June 1854, attracted by a salary five times greater than he was then receiving. He was supported by glowing testimonials from some of the leading scientists of the day, including Adam Sedgwick, John S. Henslow of Cambridge, William Whewell of Cambridge, and Sir Roderick Murchison. McCoy competed with over 90 other candidates. Whilst he was seeking support for his application, he was privately grieving for the loss of a daughter who died in late May or early June (Henry 1854), so the joy surrounding his appointment to Melbourne was tempered by bereavement. McCoy, his wife and the two surviving children, Emily and Frederick Henry, (another child had died in 1852) left England aboard *Champion of the Seas*, arriving in Melbourne in December 1854.

Acknowledgements

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Frederick McCoy and his Contributions to Stratigraphical Palaeontology

Doug McCann[1]

Abstract
Sir Frederick McCoy made a significant contribution to the foundation of stratigraphical palaeontology. He carried out extensive taxonomic work sorting, naming and describing the Palaeozoic fossils of Ireland and Britain, and also played a decisive role in the debate between Adam Sedgwick and Roderick Murchison on where to draw the boundary between the Cambrian and Silurian systems. On his arrival in the Colony of Victoria in December 1854 he found that, contrary to the expectations of most European scientists, much of the stratigraphy and palaeontology paralleled that in the Northern Hemisphere. Hence McCoy was the first to confirm that the geological column was a global phenomenon. (*The Victorian Naturalist* **118** (5), 2001, 165-177.)

Introduction

One of the most noteworthy achievements of nineteenth century geological science was the development of convenient and reliable methods for elucidating the order of succession and relative age of the earth's rock strata. The use of fossil organisms, in particular, for establishing the stratigraphical relationships of sedimentary rock sequences was a crucial step in subsequent developments in many related and newly emerging fields such as historical geology, sedimentology, economic geology, evolutionary biology and a host of other allied subdisciplines. The use of fossils for the characterisation and correlation of rock strata is commonly known as *biostratigraphy* or *stratigraphical palaeontology*. Branagan (1998a) gives a succinct, comprehensive account of the history of stratigraphy and the development of the Geological Time Scale (Zittel 1901; Gohau 1990). In this paper it is argued that Frederick McCoy played an important part in clarifying several key issues in stratigraphical palaeontology during its foundational phase.

Early work in Ireland

From the beginning of his working life McCoy was essentially a museum-based taxonomic palaeontologist. In the literature on McCoy it is often emphasised that he did little or no fieldwork – he was 'a naturalist who stayed indoors' (Fendley 1969: 135). What is sometimes implied here is that, because he mainly worked indoors sorting, describing and classifying fossil specimens and did not necessarily collect the fossils himself, there are probably limitations in the interpretations he made. However, while it is preferable that a practising taxonomic palaeontologist should examine the source locations of fossils in the field, in practice it is not always feasible to do so. Like most other sciences, geology and palaeontology are collective enterprises. By necessity, different aspects of the work are carried out by different specialists. Taxonomic palaeontologists often rely on the work of others whether they are field geologists and palaeontologists, amateur collectors or the general public.

Furthermore, taxonomic palaeontologists often are faced with sorting and description of huge collections. This was the case with Frederick McCoy. His early work in Ireland for the Geological Society of Dublin required him to arrange the collection of the Museum. The collection was already extant; McCoy was hired to sort, describe and arrange the collection already assembled. Similarly, in 1841 he was employed to catalogue the Henry Sirr collection of shells and fossils, and also to curate the collections of the Geological Society of Dublin and the Royal Dublin Society. At about the same time McCoy also began working for Richard Griffith, Director of the General Boundary Survey of Ireland, in order to make palaeontological determinations for a forthcoming Geological Map of Ireland. Again, he worked on fossils collected by others; the collections were made by Richard Griffith

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and staff members of the Boundary Survey. This latter work by McCoy resulted in two significant books *Synopsis of the Carboniferous Fossils of Ireland* (1844) and *Synopsis of the Silurian Fossils of Ireland* (1846). The value and accuracy of the actual descriptions and illustrations of the fossils in these historic works (Wyse Jackson and Monaghan 1994) were not diminished by the fact that McCoy was not the original collector (see Archbold, Brachiopoda, *this issue*).

When the Geological Survey of Ireland was established in 1845, McCoy was appointed as the first field surveyor (Herries Davies 1983). Captain Henry James, the local Director, had expected that McCoy, in light of his already significant experience describing fossils, would work as palaeontologist to the Survey, but the Director General of the Geological Survey of Great Britain and Ireland, Sir Henry De la Beche decided that the fossils should go to London for examination by Edward Forbes, one of the Survey's palaeontologists (Darragh 1992). McCoy was instead assigned to the Irish Survey's mapping program. For McCoy this appointment does not seem to have been a fortunate or happy one. The standard of his fieldwork and the quality of the geological maps he produced were criticised by Thomas Oldham who took over from Henry James as Local Director of the Survey (Herries Davies 1983). Oldham, who later went on to a distinguished career as head of the Geological Survey of India, castigated McCoy for numerous errors, omissions and careless work. McCoy and Oldham had previously clashed at meetings of the Geological Society of Dublin. There was obviously fairly strong personal hostility between them, but as Herries Davies (1983: 142) speculates, 'It nevertheless does seem probable that Oldham's complaint of slipshod work was grounded in fact, ... four years earlier a similar complaint had earned McCoy virtual dismissal from his curatorship at the Geological Society of Dublin'. Under Oldham's supervision McCoy's position at the Survey became increasingly untenable and in September 1846 he resigned.

Whatever the validity of the accusations against McCoy there are several points that need to be borne in mind. Firstly, there was considerable underlying hostility between McCoy and Oldham that almost certainly coloured the issues. Secondly, as Herries Davies (1983: 142) points out, 'One of McCoy's problems in 1846 may have been that he was inadequately briefed as to the duties of a field-geologist. De la Beche's *Instructions* of May 1845 had been singularly unhelpful in this respect'. Thirdly, Henry James had apparently hired McCoy hoping to draw upon his palaeontological skills; McCoy probably had similar expectations himself. Being more oriented towards the identification and classification of fossils, rather than geological mapping *per se*, it is possible that McCoy carried out his survey work without conviction or enthusiasm (see Darragh *this issue*).

Adam Sedgwick and the Woodwardian Museum

In any event, this difficult interlude did little or no harm to McCoy's future career path. As a result of his earlier work and publications McCoy had already established his reputation as a promising and competent young palaeontologist and his efforts did not go unnoticed by Professor Adam Sedgwick (1785–1873), the Woodwardian Professor of Geology at Cambridge University. Sedgwick first met McCoy in 1841 and was impressed by his work, later stating, '... when I first saw him (in 1841) he had nearly completed his volume on the Carboniferous Fossils of Ireland. His Irish works put him in the front rank of British palaeontologists' (Sedgwick and McCoy 1855: xvi). In November 1846 Sedgwick invited McCoy to arrange the collections in the Woodwardian Museum at Cambridge. Commenting on his first interactions with McCoy, Sedgwick recalled that, 'When my friend formed his first engagement with this University, he came amongst us young indeed in look; but, even then, a veteran in Palaeontology. He was well trained and ready for the task he had undertaken; and far better stored with a knowledge of the foreign standard works on Palaeontology than any man with whom I had before conversed' (Sedgwick and McCoy 1855: xvi).

The Woodwardian Museum housed a large collection that was originally established by a bequest by John Woodward (1665-1728) more than a century earlier, and had been added to considerably ever since, including many specimens collected by Sedgwick and his students over three decades. Sedgwick also supplemented and expanded the collection by the purchase of other geological collections and selected individual specimens to develop one of the finest geological museums in the world (Rudwick 1975). McCoy's initial appointment was for one year but in total he collaborated on the project with Sedgwick for nearly eight years; for three years full-time, then part-time. In 1849 McCoy was appointed to the foundation chair of Geology and Mineralogy at Queen's College Belfast. His duties included being curator of the Museum, but he continued to travel back to Cambridge to work on the collections during vacations. Sedgwick reported that McCoy approached his work with enthusiasm and 'almost incredible labour and perseverance' (Darragh 1992: 17). Sedgwick further testified that towards the completion of the project 'Professor McCoy was employed upon the Collection, not only during long hours of the day, but frequently during the late hours of the night' (Sedgwick 1855: viii). The end result was published as *A Systematic Description of the British Palaeozoic Rocks and Fossils in the Geological Museum of the University of Cambridge* (1855), a comprehensive and significant work in the history of palaeontology. One of McCoy's contemporaries, Professor Heinrich Bronn of Heidelberg, welcomed the book as 'one of the most important appearances in the literature of Palaeontology' (Fendley 1969: 134), and as Sedgwick remarked in the *Introduction*, 'Whatever may be the merits of the following work, it is one of enormous labour.'

It is clear that Sedgwick was very pleased with McCoy's contribution describing him as 'one of the very best palaeontologists in Europe'. However, it was not just McCoy's important and wide-ranging contribution to systematic palaeontology, or his dedicated work in organising the collections in the Woodwardian Museum, that elicited Sedgwick's appreciation – he had another much more personal reason to be grateful to McCoy. For a number of years before he hired McCoy, Sedgwick had been locked in an increasingly bitter geological dispute with his former friend and collaborator, Roderick Impey Murchison (1792-1871). Because of his association with Sedgwick, McCoy also became involved in the debate, and played a decisive role in its eventual resolution.

The Foundations of Stratigraphy in Great Britain

The publication of William Smith's geological map of England and Wales in 1815 signified the beginning of stratigraphical geology as an organised body of knowledge in Great Britain. Another milestone was the election of Adam Sedgwick as Woodwardian Professor of Geology at Cambridge University in 1818, although at that stage of his career he had little geological knowledge or experience. He soon made up for his lack of background and expertise by pursuing research that led to his recognition as one of the most capable geologists in Britain. He was president of the Geological Society of London from 1829 to 1831, and also the British Association in 1833. Sedgwick has been described by historian Walter Cannon as 'one of the best field geologists of all time' (Speakman 1982: preface).

Sedgwick took an early interest in geological issues associated with lithology and stratigraphy. In this, he was influenced by the work of William Conybeare. In 1822, William Conybeare and William Phillips published their handbook *Outlines of the Geology of England and Wales* that summarised the stratigraphy of England, as it was then understood, from the recent unconsolidated sediments in eastern England to the base of the Old Red Sandstone in the west. This handbook helped lay down the foundations of English stratigraphical geology and influenced the direction and content of both Sedgwick's and Murchison's subsequent geological research.

At that time, the rock strata were broadly classified into four sequences; Primary, Secondary, Tertiary and a 'Transition' sequence between the apparently unfossil-

iferous primitive Primary rocks and the Secondary rocks which were usually layered and fossiliferous. In theory, the Primary, Secondary and Tertiary rocks seemed straightforward and accessible for study, but the Transition rocks were somewhat of a mystery. The Transition rocks were usually layered or stratified but generally highly deformed, and even though fossils were known to be present they did not appear to be in great abundance. The opportunity for unravelling the true nature of this sequence beckoned to any aspiring, ambitious geologist. There was the added attraction that somewhere in the Transition sequence the exact point at which life began might be discovered. Sedgwick and Murchison decided to take up the challenge by attempting to decipher the Transition rocks in southwest Britain.

Murchison became a leading figure in nineteenth century geology (Stafford 1989). His earliest main influence was William Buckland, professor of geology at Oxford University. Murchison was seven years Sedgwick's junior and cultivated a relationship with him; benefiting from Sedgwick's geological knowledge and experience. Intensely ambitious, Murchison eventually outgrew his mentors to become one of the most influential scientists of modern times. His influence eventually extended around the globe. He achieved this by hard work and a strategic research campaign – and also by securing membership and leadership of important scientific societies, such as the Geological Society of London, which he joined in 1824 and served as president from 1831 to 1834, and again from 1841 to 1843. He was a co-founder of the Royal Geographical Society and was president for many years, enabling him to become a principal player in colonial science and exploration (Stafford 1989). His authority was further enhanced when he became Director General of the Geological Survey of Great Britain in 1855 following the death of De la Beche.

Collaboration

Murchison's collaboration with Sedgwick began in the latter half of the 1820s; they conducted field trips to Scotland (1827) and the French Alps (1829) and published lengthy memoirs in the *Transactions* of the Geological Society. In 1831 they turned their attention to the relatively unknown Transition rocks of southwest England and Wales (Fig. 1). The Transition rocks consisted mainly of thick confusing sequences of slate and the coarse, dark sandstone known as greywacke. Greywacke is grey-coloured, poorly sorted sandstone ('dirty sandstone') consisting of quartz and feldspar grains and broken rock fragments mixed with substantial amounts of clay particles. Most of these Transition rocks were folded, faulted and altered.

To make sense of the Transition sequence was a huge task, so they decided upon a division of labour. Sedgwick would tackle the older Primary and lower Transition slaty rocks of North Wales. Murchison decided on an approach from Western England into Wales from the southeast, and would tackle the upper Transition sequences which were less disturbed and, as he discovered, more fossiliferous. For several field seasons they devoted themselves to the task. Working separately, they were soon satisfied that they were studying two different but contiguous geological 'systems'. By 1834 they felt that each had identified and interpreted the major structural, lithological and palaeontological features of their respective regions. So in that year they conducted their first, and what turned out to be their only, joint field trip on the Transition rocks, in order to work out how the two systems meshed together, and where the common boundary might be.

The 1834 field trip was brief, and even though a few issues remained unresolved, the two co-workers were confident that they had done enough work to delineate two discrete geological systems and the joint boundary between them. Consequently, in 1835 Murchison designated his section as the 'Silurian' system, after an ancient British tribe that had inhabited the area. Sedgwick followed soon after with the name 'Cambrian' for the lower section, after the Roman name for Wales. In August 1835 Murchison and Sedgwick presented a joint paper before the British Association for the Advancement of Science titled *On the*

Fig. 1. Areas of Primary and Transition rocks according to Conybeare and Phillips 1822 (after Secord 1986).

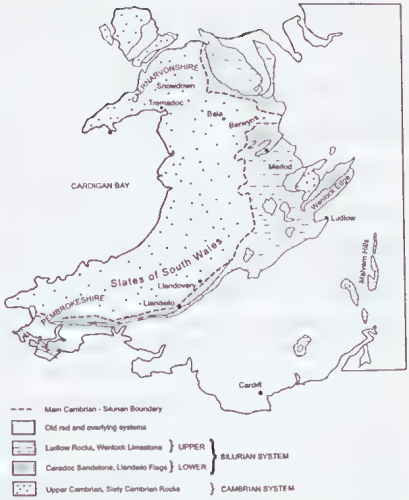

Fig. 2. Geological map of Wales showing the agreed boundary between the Cambrian and the Silurian systems, circa 1839 (after Secord 1986).

Silurian and Cambrian Systems, exhibiting the order in which the older sedimentary strata succeed each other in England and Wales. Both geologists were proud of their achievement. They were aware that their success in unravelling the structure and order of succession for the Lower Palaeozoic rocks in Britain might have global ramifications (Fig. 2).

Murchison, in particular, was determined to promote their stratigraphical interpretation of the Lower Palaeozoic rocks, or at least his version of it. In 1839 he published his classic work *The Silurian System*, one of the most significant geological publications of the nineteenth century. It was a large two-volume work, 820 pages in length, attractively illustrated, and provided a compelling rationale for recognition of his new Silurian system. His Silurian system with its characteristic invertebrate fauna rapidly gained acceptance in Europe and America. The book was dedicated to Sedgwick but in hindsight it was a dedication that probably became more of an embarrassment to Sedgwick than a tribute – particularly as Sedgwick failed to produce a similar *magnum opus* despite repeated promises to do so.

The publication of *The Silurian System* made public for the first time differences of interpretation in exactly where the boundary lay between the Cambrian and Silurian. Sedgwick was surprised to find that certain areas that he and Murchison had formerly agreed were Cambrian were now claimed by Murchison to be Silurian. Initial polite disagreement over these minor regions soon escalated into one of the major geological disputes of the nineteenth century – as Murchison in his publications progressively annexed more and more of Sedgwick's Cambrian strata until little remained.

The Cambrian-Silurian conflict

Privately and publicly, argument and counter-argument took place in this protracted debate over the next two decades as Murchison, gained the ascendancy in the debate. Early in his geological career Murchison was impressed by the importance and efficacy of fossils in determining the age and order of the rock strata (although in this he had to rely on the skills of palaeontologists such as Lonsdale, Sowerby, Salter and McCoy). While he recognised that lithology was important, Murchison became increasingly conscious of the potential of fossils to define and correlate different rock strata. His confidence was strengthened when he discovered that

Silurian rocks containing a recognisable and distinct fauna could be found. Sedgwick, by contrast, like the majority of geologists, such as Aveline, Ramsay, Selwyn and others of the Geological Survey, believed in the primacy of lithology as a basis for identifying and delimiting the stratigraphical sequence. Sedgwick viewed fossils as a secondary tool, useful when other methods were unavailable, but not reliable as the primary instrument in stratigraphical analysis.

Even though Sedgwick collected fossils on his field trips he admitted that although he knew many of them 'by sight' he did not always know them by name (Speakman 1982). Many of the fossils he collected remained unpacked and unsorted in the Cambridge Woodwardian Museum. Sedgwick was also at a disadvantage in the debate in that he was unable to establish a distinct fauna in the less fossiliferous Cambrian rocks. Instead he emphasised the immense thickness of the Cambrian strata. But as Murchison later declared: '...was the Cambrian system ever so defined, that a competent observer going into uninvestigated country could determine whether it existed there?' (Murchison 1852: 176; Berry 1968: 87). Murchison had a point; while geologists could positively identify his characteristic Silurian fossils anywhere they occurred around the globe, the best that could be said of Sedgwick's system was that it was a local entity that may or may not have implications outside his study area in Wales. Murchison was free to claim that Sedgwick's system was merely an earlier extension of the Silurian. By 1842 he was asserting that on the basis of the evidence gathered up until that time it now appeared that Sedgwick's Upper Cambrian fossils were identical with his own Lower Silurian fauna. Only a small section of unfossiliferous rocks remained of Sedgwick's original Cambrian (Fig. 3).

Sedgwick argued long and hard over the ensuing years in order to save his system. He carried out more fieldwork, he examined new areas and re-examined old ones, he put forward a number of new schemes, he invented new terminology, he was even willing to drop the name Cambrian altogether; however at this stage of the dispute he made limited progress in convincing others of the merits of his ideas. As a result of Murchison placing more and more emphasis on fossil evidence to justify his system Sedgwick was forced to take the palaeontological aspect of the work much more seriously. In 1842 he employed a young palaeontologist, John Salter, part-time, to help process the now vast collection of fossils he had accumulated over the years. Salter also accompanied him on a number of field trips to North Wales, collecting fossils in an attempt to clarify the palaeontology and even identify a discrete but simpler fauna than the Silurian (Secord 1986). Even though they discovered some new fossils, there were not enough to constitute a system distinct from the Silurian. Salter made a promising start on cataloguing the Woodwardian Museum collection but left for full-time employment at the Geological Survey of Great Britain. This again left Sedgwick with the need for the services of a palaeontologist; Frederick McCoy was hired to complete the job that had been started by Salter.

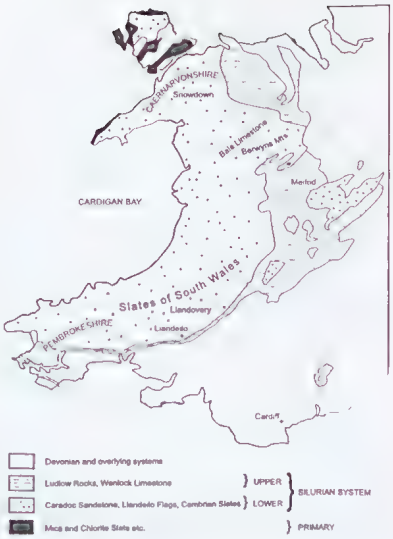

Fig. 3. Part of an 1843 map designed by Murchison for the Society for the Diffusion of Useful Knowledge (after Secord 1986). Note that in this map Murchison had extended the Silurian to cover most of Wales.

Enter Frederick McCoy

McCoy arrived at a critical stage in the Cambrian-Silurian debate. McCoy applied himself to the task of determining the fossils in the Museum but also inevitably became involved in issues related to the disagreement. It should be noted that it was not just Murchison and Sedgwick who had examined the Transition strata in question. By 1841 professional geologists of the official Geological Survey of Great Britain, who had just completed mapping of the coalfields of South Wales, began mapping in the area under dispute. John Phillips, one of the Survey's palaeontologists, reported that, in the Caradoc formation which was located towards the bottom of Murchison's Upper Silurian system, there were occasional anomalies in which Lower Silurian fossils would be found mixed with Upper Silurian. Everyone involved, including Sedgwick, believed that the Caradoc was a coherent set of so-called 'passage beds' positioned between the Silurian and the Cambrian which therefore could feasibly contain an intermediate or a mixed fauna. McCoy, however, began to suspect that possibly there were two different faunas involved, in deceptively conformable beds, but which appeared to be one lithological unit.

On examination of Caradoc fossils from a number of different localities McCoy found that they did separate out into two quite different groups – from some localities the Caradoc fossils had affinities with the Upper Silurian, from other localities the Caradoc fossils had affinities with the Lower Silurian. This strongly suggested the presence of an undetected unconformity within the Caradoc. If McCoy was correct, then Sedgwick finally had a decisive and convincing way of splitting the Transition strata into two natural systems. Sedgwick was not willing to announce these findings until he had confirmed them by examination of the Caradoc rocks in the field. In mid 1852 McCoy accompanied Sedgwick on a brief, rain-interrupted field trip which only allowed them to examine systematically the rock sections at May Hill and the Malverns, but that was enough to validate McCoy's findings and vindicate Sedgwick's claims for a separate Cambrian system. In November 1852 Sedgwick presented his results in a paper to the Geological Society. Sedgwick was able to justify subdividing the former Caradoc formation into two new groups; the upper part he named the May Hill Sandstone, this was considered to be the base of the Silurian; for the lower part he retained the name Caradoc, designated as the top of the Cambrian. The fossil gap between the Cambrian and the Silurian on this evidence was one of the largest breaks in the whole of the fossil record (Fig. 4). Sedgwick's explanation also correlated well with similar findings in Palaeozoic strata in central Europe and America.

The effect of Sedgwick's presentation on the members of the Geological Society was one of grave scepticism. At first they could not accept that the professional geologists of the Geological Survey would not have noticed that such a large geological and palaeontological divide existed between the two proposed systems. However, further work revealed that it was indeed the case. McCoy had also been present at the meeting but interestingly was not a co-author of the paper. Edward Forbes initially believed that McCoy had 'cooked' the fossil evidence in order to please Sedgwick (Secord 1986). The Survey team were in an embarrassing position – in their detailed examination and mapping of the relevant strata they had not noticed any discontinuity in the rock sequence or in the fossil record. They were forced back out in the field to re-examine critical sections and soon discovered previously unnoticed unconformities.

The Survey team tried to play down the significance of Sedgwick and McCoy's research and even suggested that they had only repeated work that had already been carried out by Phillips and others. Over the next few years Aveline, Salter and Ramsay of the Survey team, as well as Sedgwick and McCoy, carried out numerous field trips into Wales, examining rock sections, clarifying the identity and range of key groups of fossils, and revising and redrawing critical boundaries on their geological maps. It does seem somewhat ironic that McCoy, who is sometimes disparaged for the quality and quantity of his fieldwork, happened to participate in fieldwork – although admittedly in the presence of Sedgwick, one of the most famous field

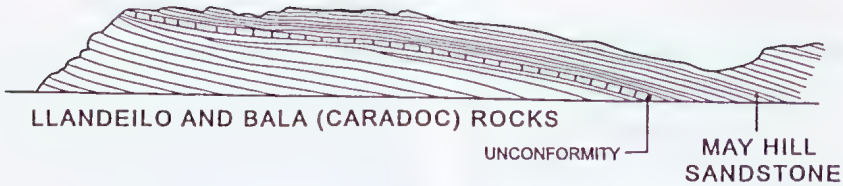

Fig. 4. Transverse section along the banks of the River Onny showing a deceptive but definite unconformity between the Llandeilo and Bala rocks (Caradoc) of the Cambrian below and the overlying May Hill Sandstone of the Silurian above (after Secord 1986).

geologists of his era – that led to the eventual resolution of one of the most intractable and historically significant disputes of the foundational period of stratigraphical palaeontology. All this was primarily the outcome of his work indoors as a 'museum-based taxonomic palaeontologist'!

Murchison, however, was not prepared to concede that he had been in error. By this time he had gained international acclaim for his work on the Silurian. Murchison felt that his whole scientific reputation would be impugned if he yielded to Sedgwick's revised Cambrian. Independently wealthy, Murchison was also institutionally in a powerful position, even more so after he became Director of the Geological Survey. Sedgwick became increasingly embittered at Murchison's unwillingness to recant, and isolated himself from the Geological Society. This played into Murchison's hands and there were suggestions by members of the Geological Survey that Sedgwick was probably going senile or insane.

McCoy's reputation, too, suffered by association. Edward Forbes satirically depicted Sedgwick as Don Quixote, and McCoy as Sancho Panza (Secord 1986). While this representation of Sedgwick displays a certain respect for his moral integrity, it strongly suggests he is fighting for a hopeless cause and perhaps a little obsessed and a little mad. McCoy, by implication, is portrayed as a blind, loyal subordinate who would do anything to please his master. One partial consequence of this is that McCoy has never received due recognition for his contribution to palaeontology and biostratigraphy. Murchison used his influence as head of the Geological Survey, and as a member of other organisations, to control the terms and direction of the debate and to resist any changes in nomenclature or in the details of the standard geological maps of which he did not approve. For ambitious younger geologists and palaeontologists' jobs were scarce and Murchison's patronage and approval were essential if they were to have any real chance of obtaining a desired position or gaining promotion; McCoy was no exception.

As the debate progressed McCoy tried to distance himself from Sedgwick although privately he remained a steadfast supporter. He tried to indicate to Murchison that he was acting objectively and without personal prejudice. Murchison was aware that McCoy was an able and self-assured palaeontologist, and even a dangerous one while he was working in league with Sedgwick. Hence, it suited him to give McCoy a glowing recommendation for the Foundation chair of Natural Science at the newly established University of Melbourne. Whether Murchison's testimonial was given because he believed that McCoy deserved the position based on merit, or simply because he wanted to get him out of the way, is difficult to say. However, it did have the effect of further isolating Sedgwick as well as removing McCoy from the mainstream history of biostratigraphy.

In the years that followed, local and international support for the Cambrian grew, but Murchison died in 1871 still opposing any change in nomenclature. The debate was more or less settled with the inclusion of the Ordovician system by Lapworth in 1879. The Ordovician system was inserted as an intermediate system between the Cambrian and Silurian systems, although it did not gain full interna-

	1	2	3	4	5	6	7	8	9
Sedgwick 1855	Silurian			Upper Cambrian	Middle Cambrian				Lower Camb.
Murchison 1859	Upper Silurian		Lower Silurian				(Primordial Silurian)		Camb.
Geological Survey 1866	Upper Silurian		Lower Silurian						Camb.
Lapworth 1866	Silurian			Ordovician			Cambrian		
	1	2	3	4	5	6	7	8	9
Principal Formations	Ludlow	Wenlock	Upper Llandovery = May Hill / Lower Llandovery	Bala = Caradoc Sandstone	Llandeilo	Arenig	Trmadoc	Lingula Flags	Longmynd

Fig. 5. Some alternative classifications for the Lower Palaeozoic rocks of Britain, 1855-1879 (after Secord 1986). Note Lapworth's inclusion of the Ordovician as a solution to the Sedgwick-Murchison impasse.

tional approval until 1960 (Secord 1986). The new Ordovician encompassed Sedgwick's Upper Cambrian and Murchison's Lower Silurian, but neither protagonist would have been at all enamoured with Lapworth's partial appropriation of their respective geological territories (Fig. 5).

McCoy in Melbourne

When McCoy arrived in the Colony of Victoria in December 1854 as one of the first four professors at the University of Melbourne (see Wilkinson *this issue*) he was only in his early thirties and already an accomplished palaeontologist. Not only was he thoroughly familiar with Irish and British fossils but he also had some experience with Australian material. In Great Britain he had worked on Australian fossils collected by Rev. W.B. Clarke and sent to Sedgwick at Cambridge. In 1847, he published a paper based on this work titled 'On the fossil botany and zoology of the rocks associated with the coal of Australia' in the *Annals and Magazine of Natural History* (see Pierson *this issue*). This familiarity with Australian fossils was possibly one of the factors that enticed him into emigrating to Australia. Soon after his arrival in Victoria, McCoy set about clarifying issues connected with the local palaeontology and stratigraphy and (with Murchison's endorsement) was appointed Palaeontologist to the Geological Survey of Victoria in 1856. He moved quickly in taking over the Colony's fledgling natural history museum and despite some spirited public opposition moved it from its city location to the grounds of the University of Melbourne (Pescott 1954; Wilkinson 1996; Rasmussen *this issue*).

The Global Geological Column

In 1861 McCoy published in the Victorian Exhibition Catalogue the first summary of the zoology and palaeontology of Victoria (McCoy 1861). This paper was reprinted in 1862 in the *Annals and Magazine of Natural History*. In the paper McCoy showed that based on palaeontological evidence the geological column in Australia conformed to that of Great Britain, Europe and North America. For the first time it was confirmed that the rock sequences in the Southern Hemisphere, despite some provincialism, correlated with those of the Northern Hemisphere. In other words, the geological column as deciphered in Great Britain was almost certainly a global phenomenon.

McCoy stated that '... from the great quantity of fossils which I have lately examined as Palaeontologist to the Geological Survey of Victoria; and from evidence of this kind I can offer a sketch of the ancient successive changes of organic life in this country' (McCoy 1862: 138). He proceeded to discuss each of the major geological periods in turn. Beginning with the (Lower) Palaeozoic he asserted that:

> The Azoic [Precambrian] rocks, I can now state, were succeeded in Victoria, exactly as in Wales, Sweden, North America, and other parts of the world in the northern hemisphere, by a series of rocks enclosing fossil remains of the well-known genera and even specific types of animal life characterizing those most ancient fossiliferous strata termed Lower Silurian by Sir R. Murchison, and Cambrian by Professor Sedgwick (McCoy 1862: 138).

McCoy then went on to discuss further correspondences between Australian biostratigraphy and Northern Hemisphere biostratigraphy for the rest of the geological column, i.e., the Upper Palaeozoic, Mesozoic, Tertiary and Recent periods.

At the time of the 1861 publication evidence for the Cretaceous Period had not been positively confirmed in Australia but in 1865 McCoy was able '... to announce for the first time with certainty the existence of the Cretaceous formations in Australia' (McCoy 1865: 333) based on fossils sent to him from Queensland that included bivalves, ammonites and Ichthyosaur vertebrae. Similarly, although fossils from the Devonian Period in Australia had been earlier identified by Konig and Stutchbury their status remained uncertain. In a paper prepared for the 1866-67 Melbourne Intercolonial Exhibition (McCoy 1867a) and reprinted in the *Annals and Magazine of Natural History* in 1867 McCoy claimed that he had definitely confirmed the presence of the Devonian in Australia based on marine fossils from Buchan in Gippsland. McCoy declared:

> It is with great pleasure I announce the fact of my having been able satisfactorily to determine the existence of this formation also in Australia, the limestone of Buchan in Gippsland containing characteristic corals, Placodermatous fish, and abundance of the *Spirifera laevicostata*, perfectly identical with specimens from the European Devonian Limestones of the Eifel (McCoy 1867b: 198).

For McCoy, the confirmation of these formations filled in the remaining major gaps in the geological record for Australia and demonstrated that there was an almost complete correspondence between northern hemisphere and southern hemisphere stratigraphy.

A shortened version of this paper was also made available for a North American audience and published in *The American Journal of Science and Arts* edited by Benjamin Silliman and James Dana (McCoy 1867c: 279-282). When discussing the Cambrian he reiterated:

> ... we have in these formations the most extraordinary proof of the unexpected fact which I announced on a former occasion, that there was in the Cambrian or Lower Silurian period a nearly complete specific uniformity of the marine faunas, not only over the whole northern hemisphere, but across the tropics, extending to this remote temperate latitude of the southern hemisphere (McCoy 1867c: 280).

In his conclusion to both of the above papers McCoy reminded the reader that he had been instrumental in contributing to the solution of the Cambrian-Silurian debate and that exactly the same geological situation prevailed in Australia as in Great Britain. McCoy concluded:

> I can scarcely close ... without drawing attention to the curious confirmation offered

> in Victorian geology of the view of Professor Sedgwick and myself, that there was a real systematic line of division between the Upper Silurian and the Cambrian and Lower Silurian, at the base of the Mayhill Sandstone and over the Caradoc Sandstone – the Mayhill Sandstone, which we first defined and demonstrated to have Upper-Silurian fossils only, and the true Caradoc Sandstone full exclusively of Lower-Silurian or Cambrian types... The Mayhill Sandstone was one of the first formations I recognized, on landing near Melbourne, with the usual Upper-Silurian fossils; and it is now found here, as in Wales, to be slightly unconformable to the Cambrian or Lower Silurian, forming the obvious base of the former and totally distinct [in fossils] from the latter (McCoy 1867b: 201-202; McCoy 1867c: 282).

Of course it should be acknowledged that McCoy's claims for the correlation of the Australian stratigraphy with Northern Hemisphere stratigraphy were based not only on his own work but also built on the earlier work of other geologists, particularly collections by T.L. Mitchell, L. Leichhardt, P.E. Strzelecki, J.B. Jukes, W.B. Clarke, S. Stutchbury and others (Vallance 1975; Branagan 1998). Many of the early fossils found in Australia were sent to Britain, Europe and America for identification by palaeontologists such as William Lonsdale, John Morris, Richard Owen, James Dana, Édouard de Verneuil, Laurent de Koninck and Alcide d'Orbigny, and, indeed, McCoy himself. Nevertheless, it was McCoy who was the first to publish a synthesis, indicating that he was the first to fully grasp the broader implications of the local geology, palaeontology and stratigraphy and place it in a global context. Few people could have been better prepared than McCoy to appreciate the Australian stratigraphy and be able to relate it back to the Northern Hemisphere situation. As Sedgwick's assistant, he had played a subordinate but vital role in examining fossil evidence and relating it to the structure and lithology of a geological formation or region.

There was another factor in McCoy's readiness to fit Australian geology into a larger framework. He was attempting to defend a 'progressionist' but non-evolutionary view of the world. McCoy's geological view of the earth, like his mentor Adam Sedgwick's, was more compatible with classical Cuverian catastrophism than with Lyellian uniformitarianism. McCoy was staunchly anti-Darwinian and believed in successive progressive 'creations'; for example, in the 1862 paper when he speaks of the change from the Mesozoic to the Tertiary, he states:

> ... we find that here, as in Europe, the greater part of the country sank under the sea during the Tertiary period, and every trace of the previous creations of plants and animals was destroyed and replaced by a totally different new set, both of plants and animals, more nearly related to those now occupying the land and sea of the country (McCoy 1862: 144).

McCoy viewed these postulated successive creations in global terms.

One of the main motivations for publishing his findings on the Australian stratigraphy was to counter the argument (advanced by 'transmutationists' and 'materialists' such as T.H. Huxley and others) that evolution occurred at highly variable rates in different regions of the globe and that Australia was, in effect, an evolutionary backwater. This was a view that had gained credence ever since the time of Lamarck, with the discovery of the bivalve *Trigonia* in Australian waters (Fig. 6) and of various marsupials which were long since extinct in Europe. By demonstrating the universality of the geological column McCoy demolished that argument. Unfortunately for McCoy this induction only helped prepare the way for the acceptance of gradual transmutation or evolution of organic species.

Conclusion

Frederick McCoy made a significant contribution towards summarizing and clarifying the Australian stratigraphy based on his northern hemisphere experience. He was the first to demonstrate that the Australian geology and stratigraphy correlated well with that of the northern hemisphere – contrary to the standard European view. Debate has continued until the present day on just how complete the correlations actually are. It appears that McCoy was largely ignored by the British estab-

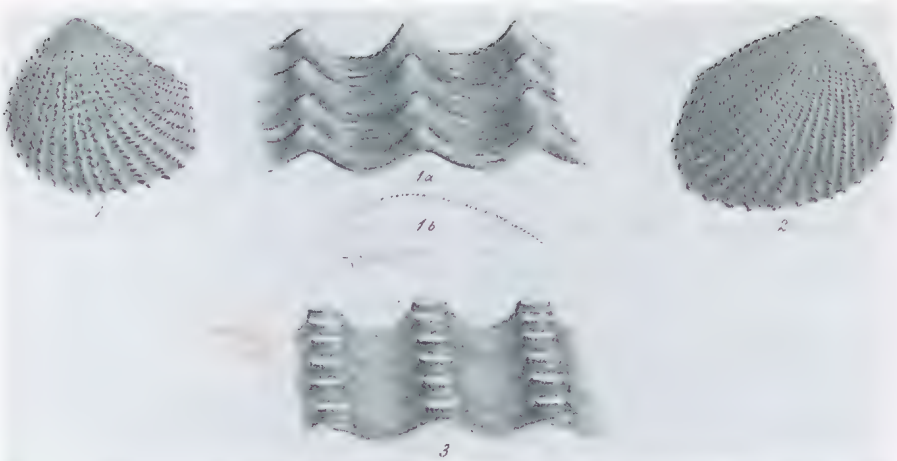

Fig. 6. Illustration of the bivalve *Trigonia acuticostata* McCoy (now *Neotrigonia acuticostata*) comparing it to the previously known *Trigonia Lamarcki* showing the acute ribs and tubercles of *T acuticostata* in contrast to the broad flattened ribs and tubercles of *T. Lamarcki*. McCoy identified and described several new species of *Trigonia*. *Trigonia* was previously known only from Mesozoic formations – and in the living state in Australian waters – but was unknown in the Tertiary. McCoy was pleased to declare that he had filled that particular gap in the fossil record. In his *Prodromus of the Palaeontology of Victoria, Decade 2* (1875) he wrote, 'Being enabled to announce the discovery of three distinct species of *Trigonia* from the Pliocene and Miocene Tertiaries near Melbourne clears away this supposed exception to a general Palaeontological law, and cannot fail to be welcome, not only to geologists generally, but to the biologists engaged with the large question of the succession of life on our globe.'

lishment in his day, and his contribution has gone almost entirely unnoticed and unacknowledged by historians.

The magnitude of McCoy's achievement is perhaps not fully appreciated today because the global geological column is now taken for granted. The realization that the southern continent was geologically compatible with Europe and America was an important confirmation of the uniformity of nature and the universality of geological phenomena. McCoy's anti-evolutionary stance, which he shared with such luminaries as Sedgwick and Murchison, is another reason that his scientific achievements have not been widely appreciated. Many of these figures have been either harshly dealt with by historians, or dismissed and ignored.

Because of his extensive commitments as Director of the National Museum, Professor of Natural Science at the University of Melbourne, and numerous other duties, McCoy never approached the prodigious output that he achieved in Great Britain. Funding difficulties and bureaucratic and political complications also contributed to delays in publication. Work on his *Prodromus of the Palaeontology of Victoria*, published serially from 1874 to 1882, was actually started in 1858 – the series remained unfinished with the seventh issue. (His *Prodromus of the Zoology of Victoria* was published in twenty issues between 1878 and 1890.)

The breadth of McCoy's contributions to palaeontology and modern zoology, his scientific, philosophical and theological activities directed at the public, and his administration of public institutions and societies, have made McCoy a difficult individual to grapple with. This difficulty should not blind us to the fact that in his day he was an eminent authority and made lasting contributions not only locally but to world science generally. He was one of the pioneering figures of international palaeontology and biostratigraphy, and until the arrival on the local scene of Ralph Tate and Robert Etheridge, Jnr. (Vallance 1978: 247) he was Australia's leading palaeontologist and arguably 'the acknowl-

edged chief of the scientific world of Australasia' (Woodward 1899: 283).

Acknowledgements
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Frederick McCoy and the Phylum Brachiopoda

N.W. Archbold[1]

Abstract
Sir Frederick McCoy, during a long career involved with taxonomy, contributed extensively to the knowledge of the fossil record of the Phylum Brachiopoda. From his classic early monographs on the fossil faunas of the Carboniferous and Silurian of Ireland, to his later works in Victoria where important new species were described and illustrated, McCoy demonstrated the same care, meticulous rigour and quality of illustrations that typified all his work. His contributions on the Brachiopoda are of high and long-lasting significance but form only part of his much broader contribution to palaeontology. (*The Victorian Naturalist* **118** (5), 2001, 178-185.)

Introduction

Representatives of the phylum Brachiopoda are, as most recently defined by Williams *et al.* (2000), 'solitary, marine, bivalved, coelomate invertebrates bilaterally symmetrical about median plane normal to surface of separation between valves; shell organophosphatic or organocarbonate, attached to substrate by muscular stalk (pedicle) or cuticular pad or secondarily cemented or free and composed of commonly larger ventral (pedicle) valve and dorsal (brachial) valve lined by folded extensions (mantle) of body wall pervaded by canaliferous extensions of coelom ... feeding organ lophophore ... disposed and suspended between mantles; alimentary canal with or without anus ... circulatory (haemal) system open ... coelom schizocoelic or enterocoelic; mostly dioecious'. The phylum is well defined and in the latest classification scheme, based on a cladistic approach, is divided into three subphyla: the Linguliformea (the 'lingulids'), the Craniiformea (the 'craniids') and the Rhynchonelliformea (brachiopods with articulated calcite shells). Investigations based on the brachiopod genome indicate that 'the traditional system of two brachiopod classes appears to be valid' (Cohen and Gawthorp 1997). The traditional system refers to the recognition of two classes within the phylum – the Inarticulata and the Articulata. Brachiopods first appeared in the geological record during the Early Cambrian and the phylum has living representatives today. They were dominant in the shallow marine benthonic environments of the Palaeozoic Era, suffered a catastrophic extinction at the end of the Permian Period, rebounded somewhat in the Triassic Period but progressively diminished during the Mesozoic Era. The Cenozoic Era brachiopod faunas are restricted but genera are relatively plentiful. Living forms, usefully divided into 'generalist' and 'specialist' genera, can dominate ecological niches and communities (Richardson 1997). Close to Melbourne, in Western Port, shallow marine benthonic communities can be dominated by the brachiopod species *Magellania flavescens* (Lamarck).

Given the above, it is scarcely surprising that during his long palaeontological career, Frederick McCoy was to appreciate the value of the phylum in the fossil record. He described many species and a number of genera during his lifetime. The present review considers his career in three countries (Ireland, England and Australia) and, while he described few brachiopods during his long time in Australia, he nevertheless still appreciated the value of the phylum for dating sedimentary sequences. Tate (1893: 27) was to note that 'the rapid unfolding of the geological structure of Victoria ... (was) aided by the palaeontological determinations of Professor McCoy'. An excellent history of the classification of the phylum Brachiopoda has been provided by Muir-Wood (1955).

Ireland

The young Frederick McCoy (Fellow of the Geological Society, Dublin) set to work with vigour on the extensive Carboniferous Limestone System fossil collections made by Richard Griffith (later

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Sir) and friends, so that by 1841 much of the work had been completed. He was to describe upwards of four hundred and fifty new species of fossil organisms. After much of the work had been printed off, he was to receive a copy of parts 1 to 12 of de Koninck's (1842) work on the Carboniferous of Belgium. The appearance of de Koninck's work required McCoy to add a note to his own work in order to clarify the minor overlap between the two monographs. McCoy's work appeared in 1844 and included, in modern taxonomic terms, fossil Cephalopoda, Gastropoda, Bivalvia, Conulata, Brachiopoda, Trilobita, Ostracoda, Annelida, Echinodermata, Coelenterata and Bryozoa. This list serves to indicate the breadth of his abilities at taxonomic research at such a young age.

McCoy's treatment of the Brachiopoda in his Carboniferous monograph commences with a succinct review of prior classifications and discusses in detail those proposed by von Buch (1834) and Phillips (1841). He then discusses the function and arrangement of the living components of the brachiopod organism and agreed that the 'tubular arms' of the brachiopod (lophophore as now used) 'served the animal for securing its prey'. McCoy's classification of the Brachiopoda included five families as follows:

1. Delthyridae, or spirifers;
2. Athyridae, or productas;
3. Orbiculidae, the orbiculas;
4. Terebratulidae, true terebratulas; and
5. Pentameridae, chambered brachiopods.

It is of interest that he excluded *Lingula* from the 'true Brachiopoda' – perhaps a forerunner in the argument for two distinct classes? He proceeded to describe species of the Orbiculidae (genus *Orbicula* only), the Athyridae (genera *Crania, Calceola, Producta, Leptagonia, Leptaena* and *Orthis*!), the Delthyridae (genera *Spirifera* – including the subgenera *Cyrtia* and *Fusella* – *Martinia, Athyris, Brachythyris* and *Orthis*). *Reticularia* and *Actinoconchus* were also included in the Delthyridae. The final descriptions were of the Terebratulidae (genera *Atrypa* and *Seminula*). The genus *Orthis* was included by McCoy in his classification of the Delthyridae although the species attributed to the genus were included under the Athyridae in the text (1844). His ideas on the position of the genus are clear and it can be speculated that the species descriptions were included in the incorrect place in the text during typesetting of the book.

McCoy (1844) analysed in meticulous detail the interior structure of the dorsal valve of productids. He interpreted what are now known as the dorsal adductor muscle scars as being modifications of the 'spiral appendages of *Spirifer*'. The brachial ridges were interpreted as being 'the principal pair of adductors'. Although he confused the two sets of structures, he anticipated the description of the schizolophe and ptycholophous styles of lophophore. He noted that in those brachiopods which have the dorsal valve flat, 'the arms are coiled so that their bases rest on its surface ... are always fixed ... to the internal face of the ventral [now dorsal] valve, and project but slightly from it'.

McCoy (1844) provided synopses and distinguishing characters for 231 species of Irish Carboniferous brachiopods of which 60 were newly diagnosed. All new species, except two, were illustrated, a large number of the illustrations were 'entirely from' McCoy's 'own pencil, and the others have been most carefully corrected, both as to outline, measurements, and effect, by my own hand' (McCoy 1844: v).

By May 1845, McCoy had completed his Synopsis of the Silurian fossils of Ireland (1846) which was to include 96 species of brachiopods of which 29 were new. The 67 previously described species were not figured and no diagnoses were provided – only localities were listed with references to previous authors. As with his previous Synopsis, fossil representatives of some 12 phyla in modern terms were described in total. All figures were drawn by McCoy but he noted that the details on the lithographic plates 'had become effaced through absorption', and that he was unable to supervise directly the production of the lithographs.

It would appear then, that by the age of 23, Frederick McCoy was the author of two major monographs (1844, 1846) and several minor works (Darragh 1992). It is clear from the references cited by McCoy that he possessed an excellent knowledge of earlier and contemporary palaeontologi-

cal literature. With respect to the literature on Brachiopoda, he was clearly familiar with the publications of British and continental European workers. The works of authors such as William Martin (1809), James Sowerby (1812), James de Carle Sowerby (1823), and John Phillips (1836, 1841) in England were often quoted and their species recognised. Works from Sweden (Dalman 1828), Belgium (de Koninck 1842), Germany (von Buch 1834, 1838, 1842; von Schlottheim 1813, 1820: note the two spellings of Schlottheim in the references provided herein – both are correct) and the Russian Empire (Pander 1830; Fischer von Waldheim 1837) were widely utilised as were many others. Sedgwick was to note in 1852 (Sedgwick 1855: xvi) that he considered McCoy to 'be one of the very best palaeontologists in Europe' and that not one of Sedgwick's friends had 'so large an historical knowledge of foreign works on Palaeontology'. Not only did McCoy have a deep knowledge of the literature but it must be noted that his illustrations of new species were also of exceptional quality for their time. They were as accurately drawn as possible, usually showing the imperfections of the specimens and were less simplified (c.f. Phillips 1836, 1841) or idealised (c.f. de Koninck 1842) than those of other authors (see and compare Figs 1 and 2 herein). It is noteworthy that von Zittel (1901: 451) considered that the works of de Koninck, McCoy and Phillips were 'still the basis of all European research on the faunas of the Carboniferous Limestone'.

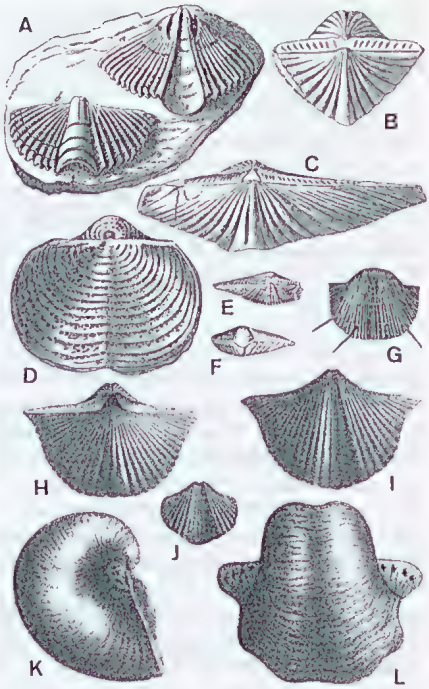

Fig. 1. Representative illustrations of brachiopods available to Frederick McCoy for his classic studies of the 1840s. Original nomenclature of authors preserved. A, *Hysterolites hystericus* (von Schlotheim 1820, pl. 29, figs 1a, b). B, *Spirifera triangularis* Sowerby (Phillips 1836, pl. 9, fig. 12). C, *Spirifera convoluta* (Phillips 1836, pl. 9, fig. 7). D, *Producta punctata* Sowerby, (Phillips 1836, pl. 8, fig. 10). E, F, *Spirifera fusiformis* Sowerby in Phillips 1836, pl. 9, figs 10, 11. G, *Producta setosa* Phillips 1836, pl. 8, fig. 9. H, I, *Spirifer striatus* Martin (de Koninck 1842, pl. 16, figs 3a, b). J, *Spirifer attenuatus* Sowerby (de Koninck 1842, pl. 16, fig. 2f). K, L, *Productus sublaevis* (de Koninck 1842, pl. 10, figs 1d, c). All figures × 0.5.

England

After a brief stint at the Geological Survey of Ireland (May 1845-September 1846), McCoy joined Adam Sedgwick at Cambridge University for what was to become a three year appointment in order to arrange the British and Foreign palaeontological collections as preserved in the Woodwardian Museum (Sedgwick 1855; Darragh 1992).

It would appear that his first task was to describe and illustrate fossils from the Late Palaeozoic of the Sydney Basin, sent to Sedgwick by W.B. Clarke of Sydney (McCoy 1847, 1851d). The Clarke collections included what are now known to be true Carboniferous and true Permian species of brachiopods. Some 25 species of brachiopods are recorded. As was typical of McCoy's style, specimens assigned to previously described species were neither described nor figured but locality data were provided. New species, nine in number, were diagnosed and illustrated. As with previous works the drawings were by McCoy and are of an excellent quality (Fig. 2). These collections were to play a crucial role in the subsequent debate between McCoy and Clarke over the age of the New

South Wales coal measures and those of Victoria, as well as the recognition of Permian rocks in eastern Australia in general (see Vallance 1981; Archbold 1986).

The idea of a work on the British Palaeozoic fossils in the Cambridge Museum was not part of McCoy's original appointment but came about in 1849 at the personal request of Sedgwick (1855: vii). Later that same year, McCoy was elected to a Professorship at Queen's College, Belfast. McCoy was to continue the work on the Cambridge collections part-time over several years. Indeed, he and Sedgwick were to enjoy eight years' working together 'without a moment's abatement of mutual good-will' (Sedgwick 1855: xvi). Sedgwick went on to record 'that in the list of those whom I have rejoiced to call my friends there has not been one more single-minded, more truth-loving and honourable than Professor McCoy'. McCoy, for his part, published only short papers on his progressive results prior to the three large fasciculi of the total volume (Sedgwick and McCoy 1855). Three short papers (McCoy 1851a, b, 1852a) documented 20 new Cambro-Silurian species, 4 new Devonian species and 11 new Carboniferous species of brachiopods respectively. The bulk of the species of brachiopods and the illustrations of the new species were left for the illustrated fasciculi (McCoy 1851c, 1852b, 1855). Sedgwick (1855: v-vi) was to express some concern over the fact that his name was on the title page of McCoy's massive work. He noted that he had 'not been a perfectly free agent in the matter', but that the Syndics of Cambridge University Press had made it a 'positive condition (arising out of existing regulations)'.

In the second fasciculus (1852b), within the class Palliobranchiata, McCoy recognised two orders. Within the first order, Rudistes, he included the family Thecidae (a group of true brachiopods), and within his second order, Brachiopoda, he included 11 families: Craniadae, Orbiculidae, Terebratulidae, Magasidae, Spiriferidae, Uncitidae, Rhynchonellidae, Orthisidae, Productidae, Calceolidae and the Lingulidae. He described just over 20 new species and several varieties from the 'Cambro-Silurian' (c.f. McCoy 1851a) and recorded over ninety additional species from this age group. From the Devonian only four species were new out of a total record of 26 species. In the second fasciculus, McCoy (1852b: 191) endeavoured to clarify the confusion over the names of the two valves of the brachiopod shell. As he had succinctly summarised in his short paper (1852a: 391): 'As the terms "dorsal and ventral" have been almost invariably misapplied by conchological writers in describing brachiopods, and as the confusion is very great when we use these terms in accordance with their anatomical position (but contrary to common use), I propose to use "receiving valve" for the perforated valve of *Terebratula*, &c. (called "dorsal valve" by conchologists and "ventral valve" by anatomists), and I use "entering valve" for the opposite one, of which the beak enters the cavity of the receiving valve'. In modern terminology, the entering valve is the dorsal valve and the receiving valve is the ventral valve.

The third fasciculus (1855) was to include some 115 species and varieties of which about a dozen were new (c.f. 1852a) for the Carboniferous and Permian. McCoy, therefore, had a wide experience of the phylum from throughout the Palaeozoic Era, which was to assist in using the phylum for age determination when he was to relocate to Victoria. All of McCoy's short papers on newly recognised fossil species in the Cambridge collections were brought together and published in book form (McCoy 1854).

Early in his work on the Cambridge collections, McCoy was to determine the functional morphology of the musculature of the brachiopod. This was published by Woodward (1851) who neither claimed the discovery nor attributed it to any other author. Sedgwick (1855: xi-xii) argued lengthily that McCoy was the discoverer of the functional arrangement (McCoy 1852b). From Sedgwick's account, it appears that McCoy determined the function in 1848 or early 1849 and widely shared the discovery with those palaeontologists who were interested in it. Smith (1987) has made much of the argument between Woodward and McCoy but does not refer to Sedgwick's account. Smith (1987: 87), when writing of McCoy's clas-

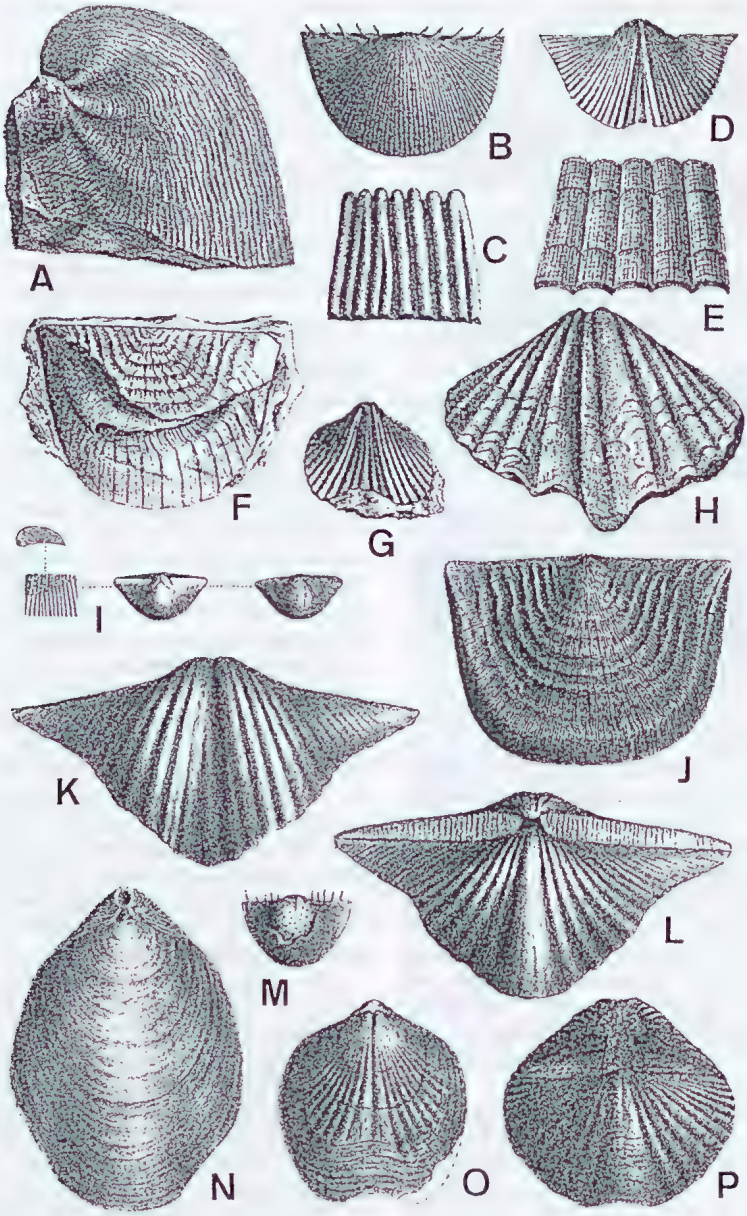

Fig. 2. Representative illustrations of brachiopods by Frederick McCoy from 1844 to 1877. Original nomenclature of McCoy preserved. A, *Producta corrugata* McCoy 1844, pl. 20, fig. 13. B, C, *Leptaena sulcata* McCoy 1844, pl. 20, fig. 6. D, E, *Spirifer clathrata* McCoy 1844, pl. 19, fig. 9. F, *Leptagonia semiovalis* McCoy 1846, pl. 3, fig. 6. G, *Atrypa serrata* McCoy 1846, pl. 3, fig. 29. H, *Spirifera duodecimcostata* McCoy 1847, pl. 17, fig. 2. I, *Leptaena tenuissimestriata* McCoy 1851c, pl. 1H, figs 44, 44a-c. J. *Leptaena undata* McCoy 1851c, pl.1H, fig. 38. K, L, *Spirifera grandicostata* McCoy 1855, pl. 3D, figs 29, 29b. M, *Leptaena (Chonetes) polita* McCoy 1855, pl. 3D, fig. 30. N, *Waldheimia corioensis* McCoy 1877, pl. 43, fig. 1. O, *Trematospira liopleura* McCoy 1877, pl. 46, fig. 3b. P, *Spirifera laevicosta* Valenciennes, (McCoy 1876, pl. 35, fig. 2). All figures × 0.8.

sified and arranged fossils, accused McCoy of 'a high-handed but probably justified proceeding' in that McCoy 'attributed the identification of about half of them to himself'. The statistics for the Brachiopoda, as outlined above, do not support this assertion.

By 1854 McCoy was clearly one of the leading palaeontologists of Europe; his speciality was the fossil record of the Palaeozoic Era. With this background he was to find rich new fields in Victoria, Australia, although his further contributions to the study of Brachiopoda were to be relatively minor.

Australia

McCoy arrived in Melbourne late in 1854 and after taking up his position of Professor of Natural Science at the new University of Melbourne he also became Palaeontologist to the Geological Survey in 1856 and Director of the National Museum of Victoria in 1858 (Darragh 1992).

These three responsibilities and his subsequent broader role of describing and curating the living world (minus Botany, which was the responsibility of Ferdinand von Mueller) as well as the fossil world, dispersed his energies. His contributions to the study of brachiopods were relegated to their use in stratigraphical dating and, after some 20 years in Victoria, the publication of descriptions of a small number of Palaeozoic and Tertiary species.

McCoy wrote little in his first few years in Victoria but the brachiopod *Rhynchonella* featured in his Prefatory Essay (1861: 166; 1862: 144) in reference to Mesozoic marine fauna from Wollumbilla Creek, Queensland. McCoy's identification had also been announced by Clarke (1862: 245) as well as the identification by McCoy of Permian brachiopod fossils (two very like *Productus calva*, Sow., and one allied to *Aulosteges* or *Strophalosia*) from the Mantuan Downs – now known to be a true Permian area in the Bowen Basin. The latter's 'great resemblance to common European Magnesian Limestone and Zechstein species' was noted by McCoy when he published an account of the Queensland fossils (McCoy identified in 1861 but published 1865).

McCoy's later summary of Victorian palaeontology (McCoy 1867a, b) provided several brachiopod identifications. From the 'Cambro-Silurian' (McCoy recognised a lower graptolite facies and a sandy, marly and mud-stone facies) he recorded *Siphonotreta micula* McCoy (from the graptolite beds) and *Strophomena*, *Leptagonia depressa*, *Spirifera reticularis*, and *Orthis elegantula*. From the 'Upper Silurian' he also recorded *Hemithyris diodonta* Dalman and *Pentamerus australis* McCoy. From the Devonian Buchan Limestone he recorded *Spirifera laevicostata*. The Brachiopoda of the Tertiary (Oligo-Miocene) beds, 'although not very abundant, present many representative and peculiar forms ... with ... another certainly identical with the very rare *Rhynchonella lucida* Gould, found living in the sea of Japan' (McCoy 1867b: 195).

Darragh (1992: 20) noted that in 1858 McCoy commenced a project to describe and illustrate the Victorian fossil and living fauna. Lithographic plates of fossils were produced in the late 1850s by Ludwig Becker, but publication did not commence until 1874 when the first decade of the *Prodromus of the Palaeontology of Victoria* appeared. Publication ceased with the publication of decade 7 in 1882. It appears unjust to argue that 'the record of his research' was 'hardly remarkable' for his first two decades in Victoria when financial restraints were presumably to blame for the lack of publications (c.f. Vallance 1978: 247). Brachiopod descriptions were published in Decades 4 and 5 (McCoy 1876, 1877). Devonian brachiopods *Spirifera laevicosta* (Valenciennes) and *Chonetes australis* McCoy were described in 1876. Tertiary brachiopods (*Waldheimia corioensis* McCoy, *Waldheimia macropora* McCoy) and Silurian brachiopods (*Leptaena* [*Leptagonia*] *rhomboidalis* Wilckens, *Trematospira liopleura* McCoy, *Trematospira formosa* Hall, *Spirifera plicatella* var. *macropleura* Conrad, *Spirifera sulcata* Hisinger, *Spirigerina reticularis* Linnaeus, *Rhynchonella* (*Hemithyris*) *decemplicata* Sowerby, *Nucleospira australis* McCoy and *Pentamerus australis* (McCoy) were described in 1877. McCoy directed the production of the plates which were of a very high quality. As noted by Darragh (1976: 4) the *Prodromus* is 'one of the finest

Australian palaeontological publications' and McCoy's descriptive work was exhaustive and methodical (Darragh 1992: 20).

Smith (1987: 87-88) considered that 'McCoy atrophied. Following his mentor Sedgwick, he never accepted the Ordovician epoch as a break with the Silurian ... McCoy did not fire his pupils' curiosity and seems to have produced no notable successors'. It is a shame that such a work has portrayed such a negative image of McCoy in Australia. As to the first comment, McCoy could scarcely follow Sedgwick in rejecting the Ordovician Period. Sedgwick died in 1873, and Lapworth proposed the Ordovician in 1879 (von Zittel 1901). McCoy was, in fact, well aware that there was a stratigraphical break between the 'Lower Silurian' and the 'Upper Silurian' as defined by the imperious Roderick Impey Murchison, Director of the Geological Survey of Great Britain. As for his students, Darragh (1992) has listed eight students who were to make a mark in geology, biology and engineering. One of McCoy's students, T.S. Hall, applied the term Ordovician to Victorian rocks in 1897. He carried on McCoy's work on graptolites, starting in 1892, and commenced the subdivision and zonation of Victoria's Ordovician sequence. Brown (1946: xi) considered that the 'high standard of palaeontological work which has been maintained since in Victoria owes much to the influence of Professor (later Sir Frederick) McCoy. He has left a wonderful record of published research ...'.

As Darragh (1992: 22) has noted, a good biography of McCoy has yet to be written. McCoy's contribution to the study of brachiopods is enough to ensure his ongoing reputation as a highly significant palaeontologist. He, of course, achieved far more, as this volume of *The Victorian Naturalist* demonstrates.

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Frederick McCoy and the University of Melbourne[1]

Ian Wilkinson*

Abstract
This article deals with some aspects of Frederick McCoy's association with the University of Melbourne. McCoy's early career is described in order to explain the circumstances that led to his appointment as the University of Melbourne's first science professor. McCoy's development of a national museum on the University grounds is noted and some assessment is made of his contribution to science teaching at the University. (*The Victorian Naturalist* **118** (5), 2001, 186-192.)

The establishment of the University of Melbourne

When the Council of the University of Melbourne met for the first time in May 1853 it appointed a Correspondence Committee to 'draw up the Statutes of the University and conduct the correspondence necessary for procuring suitable professors'.[2] In September the Correspondence Committee recommended that a committee sitting in London, headed by the famous scientist Sir John Herschel and the Astronomer Royal George Airy, should elect Melbourne's first four professors. Professors of Classics, mathematics, modern history and natural science were to be appointed. In early 1854 Melbourne's Chancellor, Redmond Barry, informed the selection committee that the Council wished to appoint young men, who were not in holy orders, who would not become involved in political or sectarian controversy, and who were graduates of Oxford, Cambridge, London, Dublin, Edinburgh or Glasgow universities.

On the subject of science, Barry wrote that:

> The great necessity for instruction in Geology, Mineralogy, Metallurgy, Chemistry, Natural History, and Physiology, with the attendant and collateral departments of study, is best proved by the fact, that questions of the most ordinary character are daily being referred to England; the resources of the country are as yet only partially known; and there is much reason to believe that such is mainly to be attributed to the absence hitherto of persons acquainted with the higher walks of science.[3]

He further noted that if the gentleman selected for the science department was possessed of 'practical skill', he was likely to confer 'large benefits on our society'.

The selection committee worked hard during the middle months of 1854, making its recommendations as quickly as possible so that the successful candidates would be able to travel to Melbourne in time to start teaching early in 1855.

In a letter to Barry in August 1854, informing the University Council of the results of the selection committee's deliberations, Herschel explained that all the successful candidates were young men, not in holy orders, who were actively engaged in teaching. He briefly outlined the impressive academic achievements of the men selected for the classics (Henry Rowe), mathematics (William Wilson) and modern history (William Hearn) chairs and then dealt more fully with the career of Frederick McCoy (natural science) who had been selected without holding a university degree. Herschel wrote:

> Mr McCoy having been brought up to the Medical Profession claims no academical distinctions of this nature but, independent of the consideration that such distinctions are not usually or necessarily associated with or evidence of eminence in that department of knowledge, the pretensions of Mr McCoy as an original authority, and as a most successful cultivator of Science are of the very highest kind and such as far to outweigh in the opinion of your committee the absence of such Educational marks of Juvenile application.[4]

Herschel's remarks reflect the fact that, although reform in the mid-nineteenth century had provided a place for the study of science and other 'modern' subjects in the curriculum of the English universities, pre-

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eminence in science was still considered to be won more through practical than academic achievements. Although Frederick McCoy had completed some university study and was, at the time of his appointment to the Melbourne science chair, a professor in one of the colleges of the recently established Queen's University of Ireland, he had gained his scientific reputation more through museum and field work than through academic distinction.

McCoy won the Melbourne science chair over a strong field of candidates, at least four of whom later had careers distinguished enough for their names to appear in the *National Dictionary of Biography*.[5] Amongst the candidates were: William (later Sir William) Aitken (1825-92), Professor of Pathology at the Army Medical School, Fort Pitt, Chatham from 1860 to 1892; William Lauder Lindsay (1829-80), a noted geologist and botanist, who combined these studies with a medical career; Henry Minchin Noad (1815-77), Professor of Chemistry at St George's Hospital, London (appointed 1847), and Consultant Chemist to the Welsh Ironworks, who wrote books on chemistry and electricity; and Edmund Rolands (1819-89), Professor of Chemistry at Queen's College, Galway from 1849 to 1856 and Director of the Bonnington Chemical Works, Edinburgh, from 1856 to 1878.

Although it is difficult to know what was in the minds of the selection committee some 150 years ago, it appears that McCoy possessed three main attributes that set him apart from the rest of the field. First, he had the ability to cover a wide range of scientific disciplines, whereas many of the other candidates were limited in their range of teaching by purely medical backgrounds. Second, he already had the status of a professor – something that few other applicants could claim. Third, he had a record of scientific achievement that was far superior to his rivals.

A brief look at McCoy's career before he came to Melbourne will show why the selection committee thought so highly of him. He drew support for his application from a distinguished group of British scientists and academics. His friend and mentor Adam Sedgwick wrote that he was 'out of all comparison' the best man for a professorship in geology, mineralogy, chemistry and natural history and that he was 'the best palaeontologist in the British Isles'.[6] A number of others endorsed his scientific qualifications and he received praise from his colleagues at Queen's College, Belfast for his teaching ability and general standing as an academic.

McCoy's early career

Frederick McCoy was born in Dublin in 1823. His father, Dr Simon McCoy, was a physician who practised in Dublin and later became foundation Professor of Materia Medica at the Queen's College, Galway. Frederick McCoy also trained for the medical profession, but never took a degree. Writing in support of McCoy's application for the Melbourne science chair, Sedgwick explained that he had had the 'education of a gentleman' and had kept 'terms' at the University of Dublin. He added that, although he believed that McCoy had met all the requirements necessary to take out a medical degree, he had become so immersed in studies in comparative anatomy, physiology and natural history that he had soon found that the medical profession offered 'few charms for him'.[7]

Sedgwick had first met McCoy in Dublin in 1841, the year in which McCoy's catalogues of the museum of the Dublin Geological Society, and the shells and organic remains of the Sirr collection in the Dublin Rotunda, were published. Around 1840 the noted geologist and engineer Sir Richard Griffith had engaged McCoy to classify his personal collection of Irish Palaeozoic fossils. The results of this work were published in *A Synopsis of the Characters of the Carboniferous Limestone Fossils of Ireland* (1844) and *A Synopsis of the Silurian Fossils of Ireland* (1846). Although McCoy's work for the Dublin Geological Society was deemed less than satisfactory and his position as the Society's Curator was terminated in February 1842, his work in a variety of settings in the early 1840s had established him as one of Ireland's most experienced palaeontologists and museum workers[8] (see McCann *this issue*).

In May 1845 McCoy joined the staff of the British Geological Survey as a field

surveyor, and, until he resigned in September 1846, worked mainly on the Geological Map of Ireland. The Survey had been reorganised in 1845, one of the important administrative changes being the incorporation of the Geological Branch of the Ordnance Survey of Ireland into the British Survey and the appointment of Captain Henry James as Local Director for Ireland. Under the direction of Henry de la Beche, the Geological Survey had become an important government scientific agency. De la Beche both strengthened and reorganised the Irish Survey, centred in Dublin, and McCoy was one of seven staff working there in 1845.[9]

McCoy's time at the Survey was not without incident. The quality of his work was questioned by some of his colleagues, including Thomas Oldham who replaced James as the Irish Director in 1846.[10] Nevertheless, McCoy left the Survey with his reputation intact and was able to return to his first love – museum work.

He now moved to Cambridge where he became Adam Sedgwick's assistant at the Woodwardian Museum. Sedgwick, who had been Cambridge's professor of geology since 1818, was a powerful figure in British geology, having carried out notable field investigations in the 1820s and 1830s with, amongst others, his later adversary Roderick Murchison.

At Cambridge McCoy's main task was the preparation of a complete catalogue of the Palaeozoic fossils in the Woodwardian Museum. He carried out this task tirelessly, resulting in the publication of *A Detailed Systematic Description of the British Palaeozoic Fossils in the Geological Museum of the University of Cambridge*, which appeared serially from 1849.[11] Following his appointment as Professor of Mineralogy and Geology in the Queen's College, Belfast in 1849, McCoy's work at the Woodwardian was curtailed, but he continued to visit Cambridge during vacations and often went on field trips with Sedgwick.

As Sedgwick's assistant, McCoy became involved in one of the most celebrated (and bitter) geological controversies in history. For some time, Sedgwick and Roderick Murchison, a former military officer who had taken up the study of geology and become a leader in the field, had been embroiled in an argument over the classification of some important rock strata in Wales. Having begun their investigations as friends and co-workers, Sedgwick and Murchison had become increasingly estranged over whether certain strata should be placed in the Silurian period, which Murchison claimed as his area of expertise, or the older Cambrian period, which Sedgwick believed was his domain. Resolution of the dispute was important because it had implications for the study of geology throughout the world – both Sedgwick's and Murchison's work being highly respected in the relatively new field of stratigraphy (the scientific study of rock strata to deduce their sequence and ages).[12]

Put simply, the dispute centred on the boundary between Silurian and Cambrian periods. Based on the fossil record, Murchison had classified certain rocks in North Wales as lower Silurian while Sedgwick had labelled them Cambrian. Neither man would yield and the dispute lingered on until well after both had died. In the 1850s (and beyond) Murchison held the upper hand in the dispute because his classifications were accepted by many contemporary geologists and by the Geological Survey. The evidence that McCoy and others supplied in support of Sedgwick was either rejected or deflected in order to ensure the integrity of the classifications in Murchison's major work, *The Silurian System*. Murchison was a powerful man within the geological community in Britain and did not want to lose face by having to abandon any part of his Silurian system. Equally, Sedgwick viewed an attack on his Cambrian classifications as evidence that his life's work was being rejected. The dispute was only settled finally by the insertion of a new classification – the Ordovician – between the Cambrian and Silurian.

As a leading member of the Geological Society in London, and later Director of the Geological Survey, Murchison was an extremely powerful scientific patron and not someone McCoy really wanted as an enemy. As a result, McCoy, who had already suffered some disadvantage in England because of his Irish-Catholic background, attempted to disassociate him-

self from Sedgwick's unpopular views to some extent, in order not to lose favour with Murchison and his supporters. His association with Sedgwick was not, however, particularly advantageous when he tried to obtain employment in London.

McCoy's future seems to have come to a head in early 1854 when the 'star position in British palaeontology' – the curatorship of the Geological Survey's fossil collections in London – became vacant. Sedgwick tried to secure this position for McCoy, but Murchison ensured that other candidates were favoured and McCoy did not obtain the position.[13] Although McCoy had accepted a chair at Queen's College in August 1849, he had done so reluctantly and had actively sought other positions ever since. Sedgwick supported him in these endeavours and suggested, in a letter to Murchison in 1852, that the British public should secure McCoy's services because he was one of the steadiest and quickest workmen to have ever undertaken the arrangement of a museum.[14] Museum work was clearly McCoy's forte and he must have been hopeful of securing a more prestigious appointment, possibly in London where the powerful Geological Society was based. In the end, though, his support for Sedgwick hindered this ambition; although recognising his ability, Murchison and his supporters were quite happy to see him established in a university in the Antipodes where he could offer Sedgwick little further assistance.

The Melbourne Science Chair

Given his desire to remain in the lively scientific community in England, a professorship in Melbourne might not seem to have been a very attractive prospect for McCoy. Nevertheless, the salary of £1000 per annum was about five times more than he was earning in Belfast,[15] and he was also guaranteed living quarters at the University, tenure for life and status as a senior scientist in the newly-established colony of Victoria. Furthermore, although there was no offer of museum work with the position, McCoy no doubt saw the prospect of developing his own little 'empire' in the Antipodes, where little geological or zoological work had yet been undertaken. While working at Cambridge, he had studied fossils collected in New South Wales by Rev. William Clarke, and had written two papers on Australian topics.[16] In Melbourne, he had the opportunity to establish a unique collection that was likely to attract considerable attention overseas because of its 'exotic' nature. Although 'transportation for life to Melbourne' meant McCoy's isolation from the centres of British science, it did provide him with secure employment and the chance to establish a museum collection of significance in an environment where he was in charge and not dependent on the patronage of others.

When McCoy and his family arrived in Melbourne just after Christmas 1854, the building that was supposed to house the new university was not complete and the prospect that the University might enrol more than a handful of students seemed remote. A lack of secondary schools in the colony meant that there was not a ready supply of students prepared to undertake the University's Bachelor of Arts course, and, initially at least, there were many who felt that its establishment had been premature. For example, when the University opened in temporary accommodation at the Exhibition Buildings with only thirteen students in attendance, *The Age* labelled it a 'costly toy' and suggested that it would be cheaper to send the students to England than to waste money on building a university in Melbourne.[17]

McCoy's early teaching at the University embraced a broad range of subjects, including zoology, comparative anatomy, botany, mineralogy, chemistry, geology and palaeontology, but the number of students in his classes was small. Increased enrolments eventually led to the appointment of additional science lecturers and professors, and the number of subjects he taught was reduced. Nevertheless, he still taught zoology, geology, mineralogy and palaeontology (Fig. 1). Toward the end of his career, his teaching was viewed as being somewhat inadequate, particularly when compared with the more 'modern' approach taken by the young science professors appointed in the 1880s – Orme Masson (chemistry), Thomas Lyle (physics) and Baldwin Spencer (biology).[18]

Fig. 1. Staff and students at University of Melbourne, c. 1876. Professor Frederick McCoy is seated first on the left in the front row. UMA/I/1306 University of Melbourne Archives.

The National Museum

Although the curatorship of a museum was not part of McCoy's duties as professor of natural science, his interest in museum work led him to seize the chance to create a 'national' museum in association with the University when the opportunity arose not long after his arrival in Melbourne.

During 1855 the Governor of Victoria, Sir Charles Hotham, who had arrived in 1854 with a brief to curtail the colony's extravagant budget, announced that public money would no longer be provided to maintain the colony's natural history collection. This collection was housed in the Offices of the Government Survey Department, but it would now have to be stored elsewhere.

Eager to show interest in the collection, McCoy visited the Colonial Secretary's Office and suggested that he would look after it (free of charge) if it was moved to the University.[19]

McCoy felt that his experience maintaining public museum collections in England made him the ideal person to manage Victoria's national collection. It had always been the Council's intention to establish a science museum in connection with the University because it believed that at least a small collection was required for teaching purposes. As McCoy provided most of the science teaching, it was his responsibility to establish a teaching museum and he argued that it would be better for both the Government and the University if this was established in conjunction with a public museum.[20]

The story of how delays in the transference of the public collection from the Survey Office to new rooms specially built for its accommodation at the University eventually led McCoy to take matters into his own hands, and bodily carry specimens from the city to the University, has been told elsewhere.[21] Suffice it to say that the idea of establishing a national museum on the University grounds did not have the support of many members of Victoria's fledgling science community and McCoy was vilified for attempting what some portrayed as a 'smash and grab' raid. In 1857 McCoy became the Director of the Museum of Natural and Applied Sciences and in 1864 a separate National Museum

building was constructed on the University grounds. The National Museum of Victoria remained there until McCoy's death in 1899. During most of his tenure as professor of natural science, McCoy's activities as museum director were probably more significant in the eyes of the Victorian public than his teaching activities at the University (see Rasmussen *this issue*).

McCoy's contribution to the teaching of science at the University

During his forty-four years as professor of natural science, Frederick McCoy witnessed many significant changes at the University of Melbourne, including the introduction of professional schools, the admission of women, the establishment of residential colleges and a huge increase in the number of students and staff. When classes began in 1855 he was virtually the sole science teacher at the University[22] and one of only a few 'professional' scientists in the Australian colonies. The fact that science subjects were not introduced into the syllabus for the University's matriculation examination until 1881 was indicative of the low status given to science education in schools and universities working on the classical English model throughout most of the nineteenth century. The establishment of an engineering course in 1861, and a medical school in 1862, produced some expansion in the University's science offerings and the first attempts were made to include laboratory work as part of science instruction. In the 1880s, chairs of chemistry, physics and biology were established and science degrees (and a science faculty) were introduced. Although science teaching still played only a minor role in the University's curriculum when McCoy died, its study had gained some credibility at both school and university level. In addition, laboratory research was beginning to become an accepted part of the University's activities.

When, in 1884, students complained of 'botany in a lecture room and not a garden', 'lectures in Zoology without practical demonstrations' and that 'no geology excursion is ever made',[23] they reflected concern that the type of science teaching McCoy offered was out-of-date. Although he was undoubtedly well qualified to take up a natural science chair in the 1850s, McCoy did not have either the knowledge or the skills that young scientists, fresh from Europe, brought to the University in the 1880s. He was basically a theoretician and a museum specialist, who spent most of his time studying indoors whilst in Melbourne.

In the twilight of his career, McCoy's mid-nineteenth-century approach to teaching and 'research' had been superseded by the more 'modern' approach of younger men. These men were not cast in the natural history tradition that had briefly come to the fore in professional science during McCoy's lifetime, but which was quickly returning to the realm of the amateur from where it had originated. For example, unlike McCoy, the biologist Baldwin Spencer, who took over some of his courses in the 1880s, had been educated in the experimental tradition and believed in the theory of evolution.[24] More significantly, when Walter Gregory became Melbourne's professor of geology and mineralogy in 1900, his appointment was heralded by *The Age* as opening 'a new era in the popularizing of University teaching in Victoria'. Adopting a vastly more practical approach to geological study than McCoy, Gregory called for new courses with field work, camping out and the linking of theoretical study with mining work.[25]

Conclusion

While McCoy eventually became associated more with the inadequacies of science teaching at the University of Melbourne than with its extension, it is clear that his distinguished career before his arrival in Australia qualified him to perform the duties required of a mid-nineteenth century natural science professor. In the latter part of his career, he completed two massive works – *Prodromus of the Zoology of Victoria* and *Prodromus of the Palaeontology of Victoria* – and received many civic and scientific awards and decorations. He also served on a number of government boards and royal commissions. He was president of the Royal Society of Victoria, founding president of the Field Naturalists' Club and a leading member of the Acclimatisation (later Zoological) Society. In addition to his Directorship of

the National Museum, he was Government Palaeontologist from 1856.[26]

As professor of natural science, McCoy helped popularise science in Victoria through the establishment of a museum that was visited by many members of the community. He left as his legacy an outstanding natural history collection that still forms part of the collection at the Melbourne Museum today.

Notes

[1] For a more detailed discussion of some of the material in this article see Wilkinson, I.R. (1996). Frederick McCoy; first science professor at the University of Melbourne. *History of Education Review*, **25** (1), 54-70.

[2] University of Melbourne, *Minutes of the Proceedings of The Council of The University of Melbourne* (*Council Minutes*), Melbourne, 3 May 1853, p. 1.

[3] *Council Minutes*, 10 April 1854, p. 3.

[4] Herschel to Barry (18 August 1854) in University of Melbourne, *Appointment of Professors Book* (Melbourne University Archives), between pp. 76 and 77.

[5] See 'Appointment of first Professors' – Microfilm, Melbourne University Archives, pp. 220-27. The candidates for the science chair are listed on pp. 225-26.

[6] Sedgwick to Airy (24 May 1854) in the *Correspondence of Sir Frederick McCoy* (2 volumes – National Museum of Victoria Library), Vol. 1 and Sedgwick to Herschel (25 May 1854) in *McCoy Correspondence*, Vol. 2. (Note: These volumes have no page numbers.)

[7] Sedgwick to Herschel (25 May 1854), *McCoy Correspondence*, Vol. 1.

[8] Herries Davies, G.L. (1995). *North from the Hook: 150 years of the Geological Survey of Ireland*, Geological Survey of Ireland, p. 21; *Australian Dictionary of Biography* (*ADB*), **5**, 134; *Nature*, **LX**, 25 May 1899, p. 83.

[9] Herries Davies (1995), 21; *ADB*, **5**, 134; Flett, J. (1937). *The First Hundred Years of the Geological Survey of Great Britain*, 46-7 and 253. (Her Majesty's Stationery Office: London.)

[10] Herries Davies (1995), 33-34.

[11] *ADB*, **5**, 134; Secord, J.A. (1986). *Controversy in Victorian Geology. The Cambrian-Silurian Dispute*, p. 244. (Princeton University Press: Princeton.); Clark, J.W. and Hughes, T.K. (1890). *The Life and Letters of the Reverend Adam Sedgwick*, 2 volumes. **II**, 193-94. (Cambridge University Press: Cambridge.)

[12] For a detailed account and analysis of the Cambrian-Silurian dispute see Secord (1986). See also Hallam, A. (1989). *Great Geological Controversies* (second edition). Chapter 3. (Oxford University Press: Oxford.) For McCoy's role see Secord (1986), Chapter 8 and Hallam, 80-81.

[13] Secord (1986), 271-72.

[14] Clark and Hughes (1890), **II**, 194. The letter from Sedgwick to Murchison is quoted as a footnote at the bottom of the page.

[15] He was earning just over £200 per annum in Belfast. See Moody, T.W. and Beckett, J.C. (1959). *Queen's, Belfast 1845-1949. The History of a University*, **II**, 703. (Faber: London.)

[16] These dealt with fossils found in the Australian coal fields. They were published in 1847. A complete list of McCoy's publications can be found in *The Geological Magazine* (1899), **6** (New Series), 285-87. There are 69 in total.

[17] *The Age*, 16 April 1855, p. 5.

[18] *ADB*, **5**, 134.

[19] See 'Memorandum re Professor McCoy's offer (regarding the museum)' dated 29 June 1855. A copy of the memorandum was included in a letter from the Colonial Secretary to the University Chancellor (10 July 1855). This is located in University of Melbourne, *Central Registry Files* (Miscellaneous Files c. 1855-1901 under 'Museum').

[20] See 'Memorandum re Professor McCoy's offer (regarding the museum)'.

[21] For a detailed discussion see Wilkinson, I.R. (1996). The Battle for the Museum: Frederick McCoy and the establishment of the National Museum of Victoria at the University of Melbourne. *Historical Records of Australian Science*, **11** (1), 1-11.

[22] William Wilson, the mathematics professor, taught some natural philosophy (roughly equivalent to modern day physics).

[23] *ADB*, **5**, 134.

[24] Finney, C. (1993). *Paradise Revealed: natural history in nineteenth-century Australia*, p. 142. (Museum of Victoria: Melbourne.)

[25] *ADB*, **9**, 100-1.

[26] *ADB*, **5**, 134-36.

McCoy's 'Living Museum'

Gwen Pascoe*

Abstract
The System Garden, a specialised botanic garden, was established at the University of Melbourne under Professor Frederick McCoy. This paper is concerned with a description of the garden and its purpose, a (speculative) explanation of the botanical system it was designed to display, and the administrative problems relating to its maintenance and decline. (*The Victorian Naturalist* **118** (5), 2001, 193-199.)

> Human bliss is popularly supposed to be represented by a scientific life, by a Professor of Botany, or the Director of a Botanic Garden or Museum.[1]

If this anonymous statement, dated 1864, is true, Frederick McCoy should have been blissful indeed, for his professional life reflected the contemporary passion for the collection, classification and display of natural history specimens. At that time he was Professor of Natural Science and controlled an almost completed botanic garden (which was later known as the 'System Garden'), and a museum which was growing in size and popularity.

Purpose and establishment

From his museum tower, McCoy could have surveyed the System Garden, which was a 'living museum'[2], designed to illustrate 'all the natural *Classes*, *Orders* and most of the *Families* and many of the *Genera* of plants, arranged with the systematic precision of the leaves of a book and fully *labelled*.'[3] When complete, the System Garden was a chamomile-edged arrangement of the plant kingdom, spread over about four acres in the north-west corner of the University grounds. It consisted of three concentric circles with radial paths leading to a central octagonal conservatory surrounded by a moat. Each class of plants occupied a large bed with a central label large enough to be read from the edge, and subsequent divisions into family, genus and species were in smaller compartments with smaller labels.[4] The carefully devised labels also contained information concerning essential structural characteristics and country of origin. Aquatic plants were exhibited in sunken tanks 'in their proper places in relation to terrestrial kinds instead of the usual practice of putting them all in one reservoir ... Even the seaweeds were kept growing for many years'. Labels in appropriate places referred to tropical plants which could only be exhibited in the conservatory.[5]

McCoy believed that students and visitors who became familiar with this arrangement of the plant kingdom would be able to understand the basis of scientific classification through observing the natural alliances and affinities of the various groups of plants. Botany lectures were given in the first term of the academic year and samples of all parts of relevant plants were required. As many plants did not flower or fruit at that time, students were to obtain specimens from the System Garden as these became available.[6] The System Garden (Fig. 1) was a formal arrangement of plants, a living herbarium which supplemented the dried specimens of a normal herbarium, and a gigantic teaching aid.

Botanic gardens played an educational role in British and Irish universities. McCoy's determination to have such a garden for his students may have been inspired by the University's first gardener. William Hyndman (c. 1822-83) had been a botanical 'porter' at Trinity College, Dublin, where he had collected botanical specimens for use in lectures and for preservation in an herbarium.[7] He was later employed at the Melbourne Botanic Garden where a system garden or 'class ground' was being established. In March 1856 McCoy endorsed his application for employment at the University with a reference to the necessity of having a 'small, rigidly systematic botanic garden' to pro-

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Fig. 1. The System Garden, 'laid out in a novel plan' c. 1865. Photo Donald McDonald. UMA/I/1154 University of Melbourne Archives.

vide specimens to illustrate botany lectures, and recommended Hyndman's engagement as a 'botanical porter' who would also superintend the laying out of the proposed garden,[8] in association with Edward La Trobe Bateman (1815?-1897).[9]

Contemporary photographs show sections of the System Garden in the 1860s to 1880s, while a fuller 'picture' is given in the planting list which appears in the Building Committee Minutes between entries for 8 November 1864 and 9 January 1865. This '1865 List' shows nearly 1500 species in the garden, hot house, frames and propagating grounds. Some plant families and individual species, especially the conifers and various genera such as *Xanthorrhoea*, *Aloe* and *Agave*, can be identified from the photographs. By aligning photographs with buildings, the position of these plants in the garden can be determined. The 1865 plant list, later correspondence and memories of the garden make it possible to fill some of the blank spaces. Professor Ewart, for example, wrote an impassioned letter about the 'destruction of the system garden' in 1909, when 'sixty-two trees and shrubs' were removed to make room for the conservatorium, which was eventually built further down Royal Parade.[10] He lists a few of these plants, which seem to have been mainly from the western side of the System Garden, though other large trees were also removed. E.J. Sonenberg, in compiling a list of System Garden plants for the Professor of Botany, John Turner, wrote of his memories of the garden, which included a depression (the remains of the moat), trees which he believed to be original, and the groups of trees which were near several identifiable features, such as the forestry glass house and the animal houses.[11] Maps and plans also provide hints about the planting. The 1896 MMBW plan shows the System Garden, but some divisions were non-existent by then. This is not surprising, as such gardens are difficult to maintain, for trees tend to outgrow smaller plants.[12]

Collectively, this information suggests that the System Garden was planted in an anticlockwise direction (perhaps in recognition that the plants were growing in the southern hemisphere), and beginning at the southern gate of the outer circle. On the basis of currently available material, the System Garden planting plan, superimposed on the 1896 MMBW plan, may have been something like Fig. 2.

Whose 'System' did the System Garden display?

McCoy was not a botanist, but his interest in classification may have encouraged him to tabulate the vegetable kingdom, for the arrangement of plants according to perceived relationships was the basis of

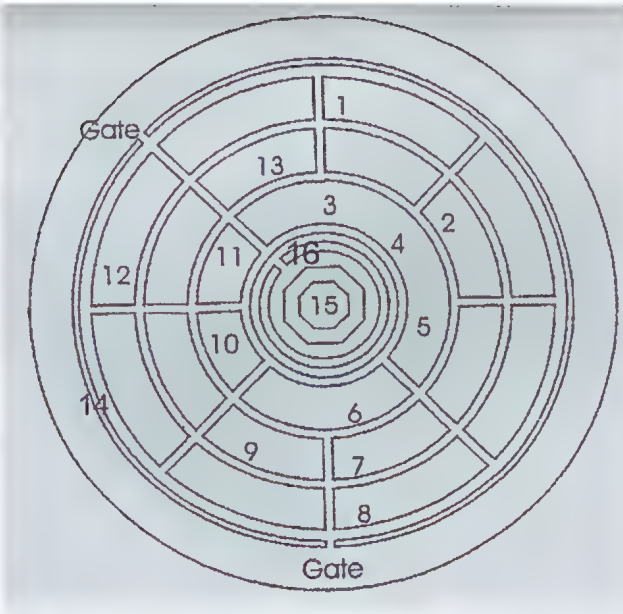

Fig. 2. A plan of the System Garden, showing some families and the main features. 1. Sapindaceae, 2. Umbelliferae, 3. Liliaceae, 4. Coniferae, 5. Casuarinaceae, 6. Artocarpaceae, 7. Myrtaceae, 8. Ranunculaceae, 9. Proteaceae, 10. Gramineae, 11. Palmae, 12. Leguminosae, 13. Compositae, 14. Hedge, 15. Conservatory, 16. Moat.

botanical 'systems'. Artificial systems were based on an obvious or convenient characteristic; the Linnaean system, for example, was based on external characteristics of the stamens. 'Natural systems', such as that which the System Garden was designed to display, were based on the comparison of morphological and physiological characteristics. The search for a 'natural system' resulted in the publication of Antoine de Jussieu's *Genera Plantarum* ... in 1789, but no single system was universally accepted, and by 1860 there were at least twenty-four 'versions' representing various botanists' attempts to devise an acceptable model.[13]

It was believed that nature revealed its own 'shape' in a natural system.[14] Many analogies were tried, including maps, reticula, grids, archipelagos, genealogical trees, constellations, even three-dimensional pyramids. As well as being interested in the 'shape' of nature, many botanists felt it important to find out where families fitted on a general scale of advancement or perfection, but as the 19th Century progressed, fewer naturalists believed in such continuity and shape.[15] The analogy used in the University garden was a triple concentric circle with radiating paths.

Features of contemporary botanical systems were progression from 'simple' to 'complex' plants, the range of plant groups included, the number of 'natural orders' (families), and the coincidence of order (family) names, or synonyms. The 1865 System Garden (S.G.) plant list moved from complex to simple, from Ranunculaceae to ferns, and included 267 families. The results of comparing this list with some contemporary versions of a 'natural system' are shown in Table 1.

This comparison shows that the closest 'match' is with Balfour's system, which appeared in the article 'Botany' in the 8th edition of the *Encyclopaedia Brittanica* vol. 5, 1854, pp. 63-239, and in his *Outlines of Botany* 2nd edition (Edinburgh, 1862).

It is not known why this system would have been chosen for the System Garden. Ferdinand von Mueller was an internationally recognised taxonomic botanist who was also establishing a 'class ground' in the Botanic Garden, but there does not appear to be any record of his having had a role in the University System Garden other than in supplying plants.[16]

The adoption of Balfour's system may have reflected admiration for its creator, John Hutton Balfour (1808-84), and for Edinburgh University, both being known for the excellence of their teaching. The successor to William Hooker at Glasgow University in 1841, Balfour was Professor of Botany (1845-79) and Medicine (1845-75) at Edinburgh, and Regius Keeper of the Royal Botanic Garden. Although

Table 1. 'Natural systems' of plants compared with the 1865 System Garden (S.G.) plant list. *Four names are missing from the 1865 List, which was apparently a copy of an earlier list.

Author	Date Published	Direction Simple (s) Complex (c)	Range	Families (number)	Names (like S.G.)
De Jussieu, A.L.	1789	s to c	Fungi to nettles	100	77
Brown, R.	1810	s to c	Ferns to Goodenoviae	58	55
De Candolle, A.P.	1813	c to s	Ranunculaceae to ferns	155	121
Meisner	1843	c to s	Ranunculaceae to Graminae	275	221
De Jussieu, A.	1844	s to c	Ferns to Compositae	226	165
Lindley	1845	s to c	Ferns to Aristolochiaceae	281	253
Balfour	c. 1854	c to s	Ranunculaceae to ferns	267	263*
Bentham & Hooker	1862-1883	c to s	Ranunculaceae to Graminae	200	178

Balfour's textbooks were standard works,[17] and McCoy brought a copy of *Outlines of Botany* with him,[18] the textbook McCoy later recommended to his botany students was Lindley's *Vegetable Kingdom.*[19] The 'Edinburgh connection' may be via Charles Babington (1808-95), John Henslow's assistant and successor at Cambridge. In 1849 Babington expressed pleasure at receiving Balfour's *Manual of Botany,* and said that both he and Henslow had recommended it.[20] It is possible that McCoy was one of those to whom the book was recommended, for he regarded them as friends and adopted their labelling system for the System Garden.[21] Another possible connection is William Hyndman, who is believed to have been a botanical assistant to William Hooker, Balfour's predecessor at Glasgow, and may have known Balfour, although he seems to have left Glasgow before 1841.[22] Dr Godfrey Howitt (1800-73) is another possible connection, for he had trained in Edinburgh and was a member of the Melbourne University Council. Whatever the connections were, for over twenty years McCoy claimed that his 'design', 'plan' or 'system' was original, as, for example, in the 1860 Building Committee Report which referred to McCoy's 'original design for illustrating the botanical arrangement of trees, plants and shrubs, on a strictly methodical plan indispensable for educational purposes of students (and) also useful for popular improvement and general scientific instruction',[23] but Balfour's contribution was not acknowledged.

In 1875, McCoy explained that he had originally laid out the System Garden 'on a new plan by which the Natural Orders were exhibited in their exact order of mutual affinity, beginning with the highest in organization and ending with the lowest' (Fig. 3). McCoy's 'originality' lay in aiming to display the whole vegetable kingdom, not just herbaceous plants and annuals, which seems to have been the usual practice.[24] It was an 'original' arrangement of an existing system, not an original system. It was a linear progression, for despite Balfour's statement that 'it is impossible to represent the affinities of plants in a linear series',[25] McCoy may have felt that the teaching value of this representation was more important than this objection. His explanation that the System Garden was 'invented by me', or was 'laid out by me on a plan which has been praised and copied by many high authorities' usually occurred when his 'territory' was under threat. Despite this innovation, 'not everything in the garden was rosy'.

Problems of administration

Bateman and Hyndman had important roles in establishing the System Garden, then moved on, while McCoy's continuing involvement made it part of his territory.

Fig. 3. Almost complete! The System Garden c. 1875. Melbourne University Gardens, Victoria. Albumen silver photograph by Charles Nettleton. The University of Melbourne Art Collection. The Russell and Mab Grimwade Miegunyah Fund.

The problems of establishing and maintaining such a garden are hard to imagine now: the soil was poor, with most of the topsoil removed, there was no reticulated water until the supply from Yan Yean was connected in late 1859, there were no herbicides, no artificial fertilisers and no machines – only (frequently inadequate) manpower and committees with little understanding of the requirements of such a specialised garden. On 9 January 1860, for example, McCoy's concern was watering, for the hose only reached the inner circle of beds in the system garden and all other water had to be carried.[26] Requests involving proposed expenditure on the System Garden appeared in the Building Committee minutes for most months, but attempts were made to curb McCoy's enthusiasm and expenditure. For example, after requesting plants which were typical of certain plant families, McCoy was given catalogues from which to make a list, which was then revised by Godfrey Howitt, who found that many of the plants were not available in Victoria.[27] On 12 July 1860, McCoy applied to the Building Committee for funds to erect a portion of the conservatory which was intended to occupy the centre of the garden. This may not have been the first such application, and it certainly was not the last, for the conservatory was not completed for another fifteen years. McCoy was at the University for forty-four years, but his turbulent relationships with administrators and gardeners resulted in the progressive contraction of the territory he controlled.

The medical school was becoming increasingly important by the 1870s, and the System Garden grounds and hothouse were required to provide plants for medical students. By 1880 the garden was overrun with weeds, neglected and largely unoccupied, 'the most prominent objects being an abundant supply of named labels, but without any specimens to represent them'.[28] Despite spirited defence by McCoy, the presentation of an alternative plan of management, and a petition signed by 160 past and present students, the System Garden was not seen as justifying the expenditure of 150 pounds per year. After twenty-five years, McCoy's management of the System Garden was over.

The System Garden was maintained by University staff, as shown in two photographs taken about 1885[29], and teaching

Fig. 4. The end of an era. The System Garden between 1916 and 1922. Photo J. Nanson.

material would still have been available. During the financially troubled 1890s, the Pharmacy College offered to maintain the garden, but withdrew over terms and conditions.[30] As the System Garden was seen as having no further educational role, the Finance Committee resolved to sell plants and buildings. Guilfoyle wrote that the Botanic Garden would gladly accept some of the palms, but the conservatory was not worth moving.[31]

Conclusion

McCoy had a vision of what the System Garden could be. In the face of public and official lack of interest and inadequate funding, the novelty of his 'original plan' wore off even before it was removed from his physical control. It was McCoy's System Garden in the sense that his influence lasted for twenty-five years, and he knew how it was designed to work. He did not try to justify the garden in terms of scientific advancement, but as a practical demonstration. With little public and academic interest, the System Garden was just too ambitious.

McCoy's contribution to the University lay in establishing the base for the teaching of science; for even though he was not remembered for being innovative, his botany students were encouraged to observe. In supporting a petition in favour of McCoy retaining control of the System Garden, Rev. E.C. Spicer wrote

> I can most truly say that nothing was of so great practical help to me in the study of botany as the access to the (system) garden where in the course of a few minutes one could see the whole vegetable world represented from the lowest to the highest in order. Often I have walked up and down the path with my books and notes and nailed if I may say so my knowledge in my mind by living examples properly arranged. I find myself referring to the garden in thought for the position of some Order I may meet.[32]

This was the purpose of the System Garden, for it was a 'living museum' designed to complement herbarium and museum collections for university students and interested members of the public. It was McCoy's arrangement of Balfour's botanical system, and displayed the Professor of Natural Science's mid 19th Century pre-Darwinian view of the plant kingdom.

* * *

A century after McCoy's death, the remains of the System Garden form a secluded oasis between the schools of Botany and Agriculture. Buildings have encroached and planting has obscured McCoy's design, but the white octagonal tower (Fig. 4) which was once the centre of the conservatory still marks the heart of the garden. This 'funny little white building' deserves to be recognised as a memorial to the System Garden of Frederick McCoy.

Notes

[1] 'Botanical lesson books. Lessons in elementary botany; the systematic part based on materials left by the late Professor Henslow ...' by Daniel Olive (1994) *Natural History Review* 4, 355-369 (Review), cited P.F. Stevens, *The Development of Biological Systematics*, p. 212. (New York.)

[2] M. Simo (1998) *Loudon and the Landscape*, p. 105. (Yale.)

[3] F. McCoy, 'Museums in Victoria', *Transactions of the Philosophical Institute of Victoria, 1856,* **1**, 131.
[4] McCoy, p. 132.
[5] 29 May 1875, 1875/17 543 University correspondence (UM).
[6] McCoy to Morrison, 6 September 1880, 1880/19 710 UM.
[7] A.W. Greig, *University Grounds* (unpaged, undated, but probably 1930s), University of Melbourne Archives (UMA).
[8] Greig, pp. 1-2; 4 July 1857 Building Committee Minutes (BCM).
[9] 31 March 1856, 27 May 1857, BCM UMA.
[10] A.J. Ewart to Dr Hill, 2 April 1909, 1909/66 UM.
[11] E.J. Sonenberg, System Garden 1946-87, 47.1 UMA.
[12] R. Schomburgk, cited T. Stephens, *Proceedings Royal Society of Tasmania 1881,* p. 38.
[13] J.R. Green (1914) *A History of Botany in the United Kingdom*, pp. 329, 336. (London.)
[14] Stevens, p. 255.
[15] D.W. Woodland (1991) *Contemporary Plant Systematics*, p. 2. (Englewood Cliffs.)
[16] Around 1972, it was believed that Mueller, rather than Bateman, had been associated with the laying out of the System Garden. Sonenberg 47.1.
[17] Green, p. 432.
[18] McCoy was repaid on 22 May 1856, Payment Vouchers (PV) UMA.
[19] Notebook of George Higgins, student 1875-78 UMA. It was previously thought that the System Garden was based on Lindley's system. S. Ducker, 'The System Garden of Melbourne University', *The Australian Garden Journal,* 5/4 April/May 1986, p. 160.
[20] C.C. Babington (1897) *Memoirs, Journal and Botanical Correspondence of Charles C. Babington*, p. 283. (Cambridge.)
[21] McCoy, p. 132.
[22] John Hyndman, great-great-grandson, personal communication, 24 November 1997.
[23] 28 May 1860, BCM UMA.
[24] W. Guilfoyle (1893) *Glimpses of Some British Gardens and their Conservatories*, p. 52. (Melbourne.)
[25] J.H. Balfour (1852-54) *Class Book of Botany*, p. 729. 3rd edition, 1871. (Edinburgh.)
[26] 9 January 1860, BCM UMA.
[27] 27 August 1860, BCM UMA.
[28] Morrison to McCoy, 6 September 1880, 1880/19 710 UM.
[29] Photographs c. 1885 – in University of Melbourne Archives, and State Library of Victoria.
[30] The proposition was made 2 October 1893 and withdrawn 5 February 1894. CM UMA.
[31] Guilfoyle to Ellery, 12 November 1894, CM UMA.
[32] Rev. E.C. Spicer, 22 April 1881, 1881/26 UM.

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Professor Frederick McCoy and the National Museum of Victoria, 1856-1899

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Based on a talk given for the History of the University Unit, Department of History, University of Melbourne, Occasional Seminar Series, 22 March 2001, based on a recently published history *A Museum for the People: a history of Museum Victoria and its predecessors, 1854-2000.*[1]

I don't presume to be an expert on Professor Frederick McCoy but in the course of working on a series of commissioned histories for the past fifteen years or so I think I have acquired some insight into directors, chief executive officers and the like, especially of public institutions in Victoria.

Foundation directors are a uniquely interesting group because they have the greatest opportunity to stamp their character on the new institution. That stamp is usually remarkably persistent – especially so in the case of Professor McCoy who took over the National Museum of Victoria only two years after its formation and presided over its development for 43 years from 1856 to 1899. Foundation directors are also uniquely interesting because the creation of new institutions suggests interesting and dynamic times, an historical moment when underlying processes of change and resistance can more easily be discerned.

I made my first acquaintance with Professor Frederick McCoy, not when I began to work on the history of Museum Victoria, but several years earlier while supervising Gwen Pascoe's honours thesis on McCoy's System Garden (see Pascoe *this issue*). I embarked on the Museum project fully aware that fitting such a complex, or should I say, contradictory, man into any neat paradigms was never going to be easy. On the other hand there is something truly seductive about the historical character who defies generalisations and stares at you, hands on hips, taunting you with the currently unfashionable question, 'What if ...?'

Today I will take the risk and argue that without Professor McCoy – for all his obvious flaws – Victoria would not have had the museum it has today. McCoy arrived at a singular moment of opportunity for one person to make a very big mark on a small canvas and, like Redmond Barry (see Carkeek *this issue*) with whom he was eventually locked in near mortal combat, he wielded a very thick brush with a confidence that bordered on hubris, except that his efforts were, I think, for the most part genuinely directed towards the benefit of the citizens of the Colony of Victoria. The *value* he added to the National Museum was a significant bequest to the nation, defined in his lifetime as the Colony of Victoria, but ultimately the whole of Australia.

'A dedicated director was of paramount importance'[2]

I am indebted to historian Susan Sheets-Pyenson for the title of this section. In her comparative study of the development of colonial museums during the late nineteenth century she observed that, 'Only those directors who possessed considerable energy and charisma could mobilize the power and financial support necessary for the survival of their institutions.'[3] Pronouncements about the centrality of director or curator in defining a museum abound in the nineteenth and early twentieth centuries, but Sheets-Pyenson stresses the extra special qualities needed by colonial 'museum builders' who 'produced remarkable institutions from almost nothing. Nearly every conceivable factor – political, economic or academic – militated against the museum builder's success in his undertaking, but remarkable individual perseverance brought eventual triumph over adversity.' The directors' intense commitment to their museums 'continued unabated for decades'. Only such 'an unwavering sense of purpose' could 'wring the

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resources they needed from parsimonious colonists'.[4] I think that Sheets-Pyenson overstates the case for museum director as *hero* and underrates the factors favouring museum development – not the least of which was the rich material to be collected, described and traded that was all around them – but if her image of natural history museums as 'cathedrals of science' stands – and I think it does – then it is not unreasonable to speak of McCoy as a *high priest*. The association of museum directors with the passion, conviction and faith of religious profession can serve to remind us that in McCoy's formative years religion and science had not yet parted company. There was still only a very rudimentary notion of a secular world view and, in McCoy's opinion (made concrete in the form of his museum exhibitions) the relationship between natural science and natural theology was not challenged by Charles Darwin's theories of natural selection and the origin of species.

At this point, since McCoy's reputation with subsequent generations has been distorted by his steadfast rejection of the theory of evolution (see Butcher *this issue*), it is important to stress that he arrived in the colony full of the latest and most exciting knowledge in his field. He was not just a man of his times but a man with a justifiable sense of himself as one of those working on the frontiers of that knowledge. His claim to be developing his *own* botanical system in the System Garden at the University of Melbourne, and similarly his claims regarding the particular arrangement of specimens in his museum, make this quite clear. He was undoubtedly imbued with a sense that there were systems and theories to be developed and that he was as well equipped as anyone he knew to help to give some final shape to those classificatory systems.

When McCoy arrived to take up his position as Professor of Natural Science at the University of Melbourne in 1854 the subject of museums would have been prominent in his thinking. Scientific teaching in that period was scarcely imaginable without some form of museum, or museum-style collection, to use for demonstrations in lectures and for systematic study by students, just as today science teaching is scarcely imaginable without access to laboratories. McCoy also needed a museum if he was to have any chance of continuing his palaeontological studies.

The original plans for the University of Melbourne had included a museum, and McCoy was dismayed to see that as things stood financially with the University, it did not have a high priority. He set to work to convince the University Council that his science course could not possibly be conducted adequately without additional accommodation for his equipment, his glass cases of mineral and botanical specimens, his pneumatic pumps and galvanic and electromagnetic apparatus.[5] He succeeded, and finance was found for a two storey building on the north side of the quadrangle (now the Law Library) which included lecture theatres and a physics laboratory on the first floor, and within a short time, the collections of the infant 'National Museum', as it became known, on the second.

The University Council also provided funds for Professor McCoy to establish a botanic garden which he intended to arrange 'with the systematic precision of leaves of a book and *fully* labelled in the way adopted in the University Botanic Garden at Cambridge'.[6] As Gwen Pascoe has suggested, 'Such a formal arrangement of plants, a living herbarium which supplemented the dried specimens of a normal herbarium, was a gigantic teaching aid'.[7] So too was a museum, but it was much more than that. Notwithstanding their obvious utilitarian and intrinsic value, museums were valued and contested symbols of power and status. Historian Dick Selleck argues, in his forthcoming history of the University of Melbourne, that in the mid-nineteenth century

> powerful men sought to hold museum keepership in their gift and, as McCoy [had] found to his cost in England, to use the giving to increase their power and their control over knowledge. Museums were also sites of the contest to improve the standing of the teaching of modern studies, particularly the natural sciences, so that it is not surprising that at Oxford and Cambridge the extension of science teaching was planned around museum areas.[8]

At the same time as systematic science gained in status, museums throughout the European world were being transformed

from idiosyncratic private collections and acquiring greater significance in intellectual and cultural life generally. McCoy wanted to be part of this process of transformation.

So too did a number of other people in the colony – or rather those who fancied themselves 'men of science' and in tune with modern developments. There were already private museum-style collections of some significance, and the Mechanics' Institute was home to a small museum. The scientifically oriented Governor La Trobe had encouraged ambitions for bigger things which had borne fruit in the establishment of a small natural history and economic geology museum. When McCoy arrived it was housed in two rooms of the Government Assay Office under the care of Surveyor-General Andrew Clarke and Government Zoologist William Blandowski.

The funding crisis that had threatened plans for a university museum also threatened the continued existence of the government-sponsored museum. The group of well-connected enthusiasts, members of the Philosophical Institute of Victoria, who saw themselves as unofficial trustees of this museum, had little power to protect or promote it in hard times. And hard times came about with a regularity that has kept all of Victoria's cultural institutions on a financial knife-edge to the present day.

McCoy was quick to see the opportunity to acquire a museum under his care, and the government was relieved to hand it over to someone willing to develop it as part of the role of Government Palaeontologist and university professor. The local museum supporters were outraged, but those with cooler heads, such as Andrew Clarke, saw more than a neat financial solution. McCoy brought intellectual authority, professional experience and international connections that could only enhance the status and prospects of the colonial museum. With hindsight it is clear that the museum was more secure than if its fate had been left in the hands of a committee of quarrelsome men with inflated egos. That McCoy soon proved inclined that way himself was unfortunate, but at least he didn't waste opportunities arguing amongst his selves over the museum's needs – and there were battles aplenty still to be fought on behalf of the Museum. Quite apart from Sheets-Pyenson's conclusions about the benefits of a single, strong-willed director, closer to home, the difficulties Gerard Krefft experienced with his trustees at the Australian Museum in Sydney – to the detriment of that museum's development – certainly bears out the point.[9]

McCoy's subsequent behaviour in building and defending this museum – his dedication to it long after many of his other passions had waned; his willingness to beg, borrow, barter, provide out of his own pocket and seriously overspend his budget, suggest an almost complete identification of himself with the National Museum. It was, as he explained to Redmond Barry, Chancellor of the University in 1856, not only his 'business' but his 'pleasure also'.

> I devote much time to the arrangement of the museum and the naming and classification of specimens, but this I do ... Because I like [where others] might wish to take exercise in the open air, or practice music, or please himself otherwise in the disposal of his time after lectures ...[10]

All this seems to justify what was an administratively correct removal of the infant museum collection to the University[11] despite the use of colourful words such as 'raid' and 'brigandage' at the time, and ever since.[12] It also tells something about the way McCoy conceptualised his own role in science and science education, and the place of a museum in that.

'The museum I am growing here'

The National Museum soon outgrew the four rooms in the north wing of the Quadrangle Building. McCoy expended much detailed thought on his requirements for the new Museum building (in the secular Gothic style of the new museum at Oxford) which opened in 1864, as well as the arrangement of the specimens with which it would be stocked (Fig. 1). The modern museum, such as McCoy wished to develop, would be defined by its specialisation, its careful and accurate classification and its visual explication of the state of knowledge at the time. The 'showy and useless' would not crowd out the 'apparently insignificant creatures that for good or evil most concern mankind'. Neither

Fig. 1. National Museum of Victoria, Melbourne, c. 1865-1889. Lithograph and watercolour by Clarence Woodhouse. The University of Melbourne Art Collection, Grimwade Bequest, 1973.

would McCoy's museum be a jumble. Labels on zoological specimens would include family, genus, species, locality and popular name. A system of Roman numerals permitted 'reference to lists painted on the walls giving the orders of all the classes of animals in full'. Mineral specimens were similarly labelled with name, locality, 'crystalline system and the chemical formula of its partial composition set forth in symbols explained by adjoining painted tables and lists'. Palaeontological specimens were

> first divided into geological groups or period according to the distribution in time and analogous to the distribution in space indicated by the arrangement of the collections of specimens of living species. The fossils of each formation are then arranged in zoological systematic order, and fully named with genus, species, locality and formation.[13]

In short, McCoy wished to provide the colonial frontier with access to a world view that was only just making itself felt in the metropolitan centres of Europe and North America. He also exhibited a deft touch in marrying his metropolitan knowledge with provincial needs and aspirations. His museum was as focused on what we would understand today as applied science – the technology for extracting ore and minerals from the earth, identifying building materials and improving agricultural production – as it was on laying out the classificatory systems of natural science. The mining models were among his most prized exhibits, for his museum was always intended to be both a site of research and of education – a place for the elite and for the ordinary, curious citizen. McCoy never intended to shut the public out of the National Museum, as his detractors in the Philosophical Institute and the daily press had claimed; quite the contrary.

Apart from his scientific mentors, McCoy was influenced by men such as the British Museum's director, Edward Forbes, whose thoughts on 'The educational Uses of Museums' were published in 1851. Within the last few years, wrote McCoy, museums had been discovered to be 'the most ready and effectual means of communicating the knowledge and experience of the experienced few to the many.' Under his direction 'the eye of the

unlearned could be familiarised with natural objects, with the principles of classification applied to them by scientific men, to place their peculiar characters and mutual relations in a striking light.'[14] This was not empty rhetoric. McCoy went to great lengths to entice visitors. The Museum was open all day from Monday to Saturday and every week he supplied the *Argus* with reports of the latest attendance statistics and descriptions of new acquisitions. Many were brief, others little essays on the latest developments or the lessons that might be learned from observing new exhibits. Something of McCoy's style of exposition can be gleaned from one such report in the *Argus* of 1 January 1860.

> The case devoted to osteology has had several additions, amongst which the skeleton of the armadillo is of great interest to naturalists and geologists, from illustrating the great geological extinct mammals belonging to the edentate group – such as the *Megatherium*, *Mylodon*, *Glyptodon*, &c. The singular structure of the bones of the limbs and shoulders, recalling, on a small scale, the peculiarities of the extinct gigantic creatures mentioned. This skeleton of the armadillo also illustrates better than that of any other Edentata the extremely interesting arguments of Dr. Buckland in his Bridgewater Treatise, and Professor Owen, touching the special peculiarity of the spinous processes of the vertebrae of the trunk to enable them to support the external body carapace (which may be seen in the stuffed specimens of armadillo in the South American cases) peculiar to the Edentata amongst warm-blooded animals, and the recognition of which peculiar development in the gigantic fossil vertebrae enabled Lord Buckland and Owen to predict the existence of a great bony external armour protecting the extinct animals alluded to before the nearly perfect shields of the *Glyptodon* now in the College of Surgeons, were known. The lovers of osteology will also find in the additions of the week to this case beautifully mounted skeletons of the jackal, the sea-eagle, the Virginian eagle-owl, and of the cobra de capella (*Naja tripudiens*), and also the skulls of the walrus, the zebra, Arabian horse, and the hippopotamus, the latter affording an interesting comparison with the fossil *Hexaprototon* from the sandstone of the Sivalik Hills in the east room. To the mining department several models of gold washing and crushing machinery have been added, and a large working model of the Freyburg *Erz muehle* or mill for grinding ores for the metallurgist; also examples of the new patent galvanic plates of Meyerhoff's patent gold-washing and amalgamating cradle, presented by the inventor, together with samples of gold amalgam and extremely fine gold saved by this machine. A fine specimen of the mantis called *Podacanthus viridiroseus*, caught in Gardiner, has been presented by Mr Vail, and another species from Beechworth, presented by Mr Roberts.

McCoy's efforts as a publicist not only attracted visitors, they helped raise the profile of science and the level of knowledge even among those who did not visit.

McCoy proved an excellent publicist with a sure instinct for what would attract popular interest. Even P.T. Barnum, whose style and circuses are so often presented as the antithesis of sober, 'dusty' museums, would have taken his hat off to the sensation created by McCoy's coup in securing a large case of Paul Du Chaillu's gorillas in 1865 – some of the very first to be seen by Europeans. They were to serve as centre piece for his orchestration of a lively debate on the theory of evolution in Melbourne and further strengthened his reputation as a man in touch with the latest developments throughout the world.[15]

By the middle of the nineteenth century science was established as an international enterprise and the building or redeveloping of museums very much the vogue.[16] Scientists in different countries engaged in regular communication and McCoy was a prodigious letter writer. Australia's place in this intellectual community may have seemed dependent and peripheral by most measures, but its role as a site of sustained interest and valuable research material for international visitors ensured that antipodean scientists would soon assume a greater degree of independence and custodianship. McCoy could draw quickly and easily on the latest museum models to plan his own, and he articulated a clear conception of where his museum sat in this scheme of things. 'The Museum I am "growing here"', he wrote to Adam

Sedgwick, was to be truly scientific, approximating the comprehensive collection which Richard Owen was at that time constructing at the Natural History Museum at South Kensington in London.[17] One of his first acts on behalf of the Museum was to seek from Owen a 'few separated skulls and other parts of skeletons ticketed and coloured and connected' to illustrate his Vertebral Theory.[18] McCoy adopted Owen's principle of displaying specimens that called attention to an animal group by accentuating a particular quality. Whale skeletons, for example, showed the enormous size attained by aquatic animals and it is easy to imagine McCoy's enthusiastic pursuit of the bones of the oversized Blue Whale *Balaenoptera musculus* that washed up on the beach at Jan Juc in 1866. The 90 foot skeleton was of necessity set up outside at the back of the museum and has not survived. At the time it was among the largest articulated specimens in any museum (see Seebeck and Warneke *next issue*).

McCoy also followed Richard Owen's example in remaining inside his museum rather than out in the field collecting. Part of the reason lay in his dual role as professor. The University had only allowed McCoy's appointment as Government Palaeontologist after assurances that the work would not interfere with his professorial duties. McCoy taught across a wide range of subjects in addition to various other commitments within the University and outside in the wider community that would not easily have allowed for lengthy expeditions. Significantly, his own reputation rested on museum study not field work, for which he had been severely criticised while working with the Geological Survey of Great Britain.[19] In any case a steady stream of material for him to work on arrived from the Geological Survey of Victoria.[20] The subsequent elevation of field trips in the work of scientists has led to some undervaluing of McCoy's legacy which included the first comprehensive account of the zoology and palaeontology of Victoria published in the Victorian Exhibition Catalogue of 1861. On the basis of his work on Victorian palaeontology McCoy was able to demonstrate that the geological column in Australia conformed to that of Great Britain, Europe and North America (see McCann *this issue*). 'For the first time it was unequivocally verified that the rock sequences in the Southern Hemisphere correlated precisely with those of the Northern Hemisphere. In other words, the geological column was a global phenomenon.'[21] This work would earn him a doctorate from Cambridge (1886) and the coveted fellowship of the Royal Society (1880).

For McCoy, as for many significant scientists of his era, the museum was central to his investigations and the ideas developed on the basis of that work. Richard Owen 'assumed that the collection, display and description of natural history objects added to the "intellectual wealth" of a nation and that the "indoor naturalist/museum curator played a significant part in this important scientific enterprise'.[22] McCoy cast himself, in the manner of Owen in London, Agassiz at Harvard and others, as builder of a 'national' collection for the benefit of all Victorians despite modifications and limitations on the model imposed by the colonial context.

McCoy's primary intention was to develop for Victorians a wide-ranging international reference or 'Index' collection in clear harmony with Ferdinand von Mueller's claim that 'the ripened work of our successors' depended on 'the timely storing up of collections for scientific use'. For McCoy such a collection was necessary if local investigators were to identify their discoveries correctly and authoritatively as they turned 'the unread pages of the Book of Nature'.[23] In explaining this McCoy drew an analogy with politics. 'As well might you expect to understand the politics of one European state without reference to the acts and laws of the others, as attempt to investigate the natural products of a colony without at least certain typical specimens from all other parts of the world'.[24] Such a collection was also essential to the provision of sound scientific education in the colony. In the long run this would strengthen the authority of younger local scientists who were disadvantaged by their limited access to education and museums in the northern hemisphere. Such authority and a good reference collection were also necessary if

Australia were to stem the flow of the most valuable material to overseas museums.

In pursuit of this reference collection McCoy immediately set about establishing a network of overseas collectors of high quality from whom to buy the specimens he required. The scope of his plans and the size of his budget are readily revealed by the first orders placed in 1857. Predictably one of the earliest went to John Gould (see Fleming *this issue*). He was asked to provide as large a collection of the generic types of 'good bird skins and for species as good [as] exemplification of the principal geographical groups' as £400 would purchase. The first consignment of 1,000 bird skins arrived the following year. These augmented the 150 North American bird skins presented by the Boston Society of Natural History in 1857 which included a pair of the now extinct Passenger Pigeon. Gould would ultimately provide ten thousand skins of birds and mammals (mostly from outside Australia) in regular consignments to the Museum until 1870.[25] J.O. Westwood was forwarded £250 to obtain 'as large a collection of generic types of insects, Crustacea and other articulata as can be obtained' accurately labelled according to the latest museum style. McCoy sought the efforts of Dr John Edward Gray, Keeper of Zoology at the British Museum, in obtaining examples of generic types and geographical groups of 'quadrupeds, British and other fishes dried flat, shells, corals, echinoderms and reptiles' to the value of £520. He was also asked to send a complete set of the British Museum catalogues. Rev. Professor Henslow of Hitcham Rectory, Suffolk was to see if he could acquire a 'copy as it were of your Museum of Economic, Botanical and Agricultural Museum at Kew'. All expenses of anyone undertaking to put this collection together would be 'cheerfully paid by the Colony whose desire it is above all things to save time or take it by the forelock'.[26]

McCoy's use of 'cheerfully' here is worth some reflection. It suggests a largesse and mood rarely associated with governments, certainly not hard-pressed colonial governments beset from every direction with urgent needs for basic infrastructure. Rather this is a transference of McCoy's own state of mind and heart. His pleasure in building Victoria's museum was immense, so immense that he could scarcely acknowledge that others might be less enthusiastic, that they might have other priorities for the spending of public money, or, in the case of collectors, that they would not mind waiting years to be paid for valuable consignments to the other side of the world.

Of these early contacts, John Gray proved a particular friend of the Museum. McCoy had not presumed to seek his personal attention, only that the 'tedious matter' of his requests be handed over to 'one of the zoological assistants', but Gray concerned himself closely with purchasing more than £3,182 worth of specimens between 1857 and 1864 when he suffered a debilitating stroke. He struck a bargain with Liverpool's Derby Museum which netted 128 mounted mammals and ten skins for less than the usual cost of stuffing alone, and spent six months attending to the mounting of 2,000 species of shells on boards and another three to name and catalogue an assortment of fish and reptiles preserved in alcohol. He offered to travel to Paris to evaluate 8,000 bird specimens offered by the Verreaux taxidermy firm and in 1863 purchased the Curtis British Insects Collection, which unaccountably had been turned down by the British Museum. Above all, Gray provided McCoy with essential introductions to professional natural history dealers and collectors in Britain and Europe where trade and commerce in such items was a flourishing business. He 'gave unstintingly of his time and talent to help the collections of a man he had never met and a museum he would never see.'[27] McCoy had managed in a remarkably short time to bring to Victoria a collection that embodied a good deal of the latest scientific understanding of the natural world.

In the first decade of his directorship McCoy enjoyed a relatively lavish budget. When this collection expenditure is added to normal running expenses and the cost of the new building opened in the grounds of the University in 1864, it amounted to over £80,000. In the new building he had far more scope to present the material according to his own view of the 'great chain of

being' and the relationship between various animal groups. Here we return to consider a man who, even after half a lifetime's exile in the colonies, never relinquished a sense of himself as a scientist capable of generating and explicating new knowledge. His geographical museum layout became a concrete expression of his rejection of the new intellectual paradigms, not only Darwin's theories of natural selection and the origin of species by evolution, but the rise of biology, physiology and laboratory-based science that threatened the status of museums far more comprehensively than these theories. This steadfast rejection was in tune with many of his fellow citizens. The published tributes of the time tended more to praise him for this than ridicule. As one writer in 1881 declared, 'It is satisfactory in this age of weak-backed men to find someone who has the courage of his opinions'.[28]

That McCoy clung to older paradigms is hardly surprising given his age, but like others with more expertise than I can demonstrate, he seems to have rejected Darwin's theory in scientific terms, as he saw them (see Butcher *this issue*). It was not simply an irrational rejection of a novel idea. He did attempt to engage with the new theories 'as a scientist' and his Museum played a significant role in that engagement. A year before his death, McCoy drafted what appears to be a letter to a daily newspaper that was never sent – or at least, never published. In outlining his version of the history of the National Museum of Victoria, the ever increasing size of his handwriting and the intensity of the corrections and underlining underscores his rising passion. The story had acquired some revealing 'errors' of fact, and there was the unusual rehearsal of complaints about poor treatment and budgetary deficiencies, but far more interesting is his resonant, if querulous and long-winded, restatement of his philosophy of museum arrangement. It requires a long quotation to do justice to McCoy's propositions and his sense of himself as no mere imitator.

> The plan and arrangement of the National Museum had from the first some special peculiarities which have been since recognised generally as adding greatly to the interest of collections arranged according to the methods in the older museums; a little explanation may now be desirable.
>
> All the zoologists well acquainted with the great number of species are agreed that the Geographical Distribution of the Species is of a great & peculiar interest not striking the attention in the old museums. There are six ... regions of the earth, all the living creatures in which are so peculiar to one or other of them that the term 'centres of creation' has sometimes been applied to them by theorists. The fact is that very few creatures are common to any two of these regions, & in the design of our National Museum there was a separate gallery for each of these great regions of the world. This gives great interest to geographical studies, and the public will readily see the zoological peculiarities of each of these regions with a distinctness not suggested by any other arrangement. ... Each of the regions has a complete Systematic Classification of all the species in its own gallery. One can see by this plan at a glance the falsity of the view held by most theorists that the differences in the structure of animals are due to their surroundings, climate &c. One can see in our Museum when finished [McCoy had been waiting 34 years for the second wing to be built] that Australia, South Africa and South America present great tracts in the same latitudes, having practically the same surroundings in all their varieties, & yet ... the fauna of each is totally different from the other two – scarcely a single species being in common & where in either of them the external circumstances would influence the habits, structure or appearance of some characteristic creature, instead of that species being common to the three similar localities they are 'represented' by singularly similar creatures in habit and general appearance, but totally distinct structurally. The Ostrich of the sandy plains of Africa, for instance, is represented in the similar plains of Australia by the Emu; and by the Rhea in the similar plains of South America. In this way the 'theory of representative forms' comes with clearer apprehension to the visitor than in any other classification. In the three birds I mentioned there could be no question of one of these forms having grown out of the other by a difference of

> surroundings, for the Ostrich has two toes, & the Australian and South American representatives three – a change not required, & all the three thriving when introduced into any one of the localities by man. The monotony in other museums of immense numbers of species of a genus showing little striking diverseness is curiously and suggestively relieved by breaking the series up into the great geographical regions or groups where the set in one country curiously represents the series in another. I believe that at present there is no known reason for those great characteristic geographical distributions and representations; but when the Museum is finished the visitors will have the means of judging for themselves on the truth of these theories, the facts, for the first time, being made clear in the initial arrangement; & children & travellers or persons studying the works of voyagers will have a peculiar pleasure in seeing all the characteristic animals of a country treated of, contrasted with those of another gallery ... [The fossil collection could also be used to reinforce his views] I have always considered the changes between the fossils of one geological formation and another comparable to the changes above referred to in the geology of the six great zoological regions of the earth at the present day. This is a new view, which I have had in mind in all the preparations of the Museum, & which will be clearly seen when the building is finished and my fine collections of fossils are displayed for inspection of the public in due systematic order; showing the world-wide distribution of species in the old time but distinctly conforming in the more recent [unclear] to the main characteristics of the geographical distribution of the living types ... of our own times.[29]

McCoy had frequently stressed the singularity of his museum arrangement – not only because it was, in his view, more scientifically valid, but because it was more entertaining and engaging. He never conceived of his museum as one where display was not integral to its purpose. His supporters certainly praised the National Museum for the absence of the 'depressing monotony' seen elsewhere in Victoria 'where all the species of one genus are displayed together' and 'one has scores of cases of birds, avenues of skeletons, a mile of rats and mice' (though the modern reader might well wonder where these other museums actually were!) All that could be dismissed as yet further evidence of McCoy's famous dogmatism, which it certainly was from one perspective. On the other hand, it was the foundation of his strategy and the source of the drive that brought to colonial Melbourne a genuinely world-class, international collection. A more humble, self-effacing man would not have prevailed to the extent that McCoy did in overcoming the huge financial and other obstacles, most notably distance, that stood in the way of his ambition. A man less convinced of the near religious significance of the knowledge embodied in the collection and its arrangement would have scaled his vision to colonial horizons – and taken fewer risks with his money and his reputation. A man less convinced of the rightness of his vision and understanding would not have bothered to gather an international, representative collection, and Victoria would have been the poorer. A high priest in his cathedral of science for nearly half a century, McCoy created a museum that was the embodiment of his own singularity and Victorians then and now are the beneficiaries of that singularity.

Notes

[1] Scribe Books in association with Museum Victoria, November 2001.

[2] S. Sheets-Pyenson (1988). 'Cathedrals of Science: The Development of Colonial Natural History Museums During the Late Nineteenth Century', p. 25. (Magill-Queen's University Press: Kingston).

[3] Ibid., 25.

[4] Ibid., 26.

[5] Blainey, G. (1957). 'A Centenary History of the University of Melbourne', p. 14. (Melbourne University Press: Melbourne.)

[6] (1856). 'Museums in Victoria' in *Transactions of the Philosophical Institute of Victoria* **1**, 131, 132.

[7] Pascoe, G. (1997). 'The University of Melbourne System Garden: Whose Garden? and Whose System?', p. 6. (BA Honours thesis, University of Melbourne.)

[8] R.J.W. Selleck, Manuscript of forthcoming History of the University of Melbourne from its foundation to World War II.

[9] See Piggot, A. and Strahan, R. (1979). 'Trustee-Ridden: 1860-74', *In* 'Rare and Curious Specimens: An Illustrated History of the Australian Museum: 1827-1979', pp. 27-36.

Eds R. Strahan *et al.* (Australian Museum: Sydney.)

[10] F. McCoy to R. Barry, 25 October 1856, McCoy Letter Book, 1. Museum Victoria Archives.

[11] McCoy could not have succeeded without the full co-operation of Surveyor-General Andrew Clarke. Indeed, a rueful Blandowski wrote to the *Argus* on 24 July 1856 to say that he had been ordered by the Commissioner of Crown Lands to pack the specimens for transmission to the University. See also Armstrong, E. La Trobe (1906). 'The Book of the Public Library, Museums and National Gallery of Victoria: 1856-1906', p. 28. (Trustees of the Public Library etc.: Melbourne.)

[12] *The Age* and the *Argus* generally supported those who opposed the move. See also, cartoon and verse in *Punch*, 14 August 1856; Sheets-Pyenson, *Cathedrals of Science*, p. 53. A. Moyal, *A Bright and Savage Land.* 1986 (1968; reprint, Ringwood: Penguin, 1993), 78.

[13] Memorandum by Professor McCoy on 'The Organisation of the National Museum of Melbourne', n.d. McCoy's papers, Museum Victoria Archives.

[14] McCoy, F. (1857). Museums in Victoria. *Transactions of the Philosophical Institute of Victoria* **1**, 127-128.

[15] *Argus*, 20 June 1865 and *The Illustrated Melbourne Post*, 25 July 1865. For an examination of this debate, see Butcher, B.W. (1988). Gorilla Warfare in Melbourne: Halford, Huxley and 'Man's Place in Nature'. *In* 'Australian Science in the Making', pp. 153-169. Ed. R.W. Home. (Cambridge University Press: Melbourne.) See also Bulcher (*this issue*).

[16] See Sheets-Pyenson, *Cathedrals of Science*, p. 9.

[17] F. McCoy to A. Sedgwick, 14 December 1857, quoted Selleck, Draft Manuscript.

[18] R.T.M. Pescott (1954). 'Collections of a Century: The History of the First Hundred Years of the National Museum of Victoria', p. 36. (National Museum of Victoria: Melbourne.)

[19] Selleck, Draft Manuscript.

[20] Sheets-Pyenson, *Cathedrals of Science,* pp. 31 and 74; ibid.

[21] McCann, D. and Archbold, N. (*in press*). Frederick McCoy and the Conformation of the Global Geological Column. *In* 'Geology of Victoria', Third Edition. Ed. W.D. Birch. Note also Jackson, N.W. and Monaghan, N.T. (1994). Frederick McCoy, An Eminent Palaeontologist and his Synopses of Irish Palaeontology of 1844 and 1846. *Geology Today* 1994, pp. 231-234. See also McCann (*this issue*).

[22] Wilkinson, I. (1996). The first science professor at the University of Melbourne. *History of Education Review* **25**, 63-4.

[23] McCoy, F. (1859). *Transactions of the Philosophical Institute of Victoria* **6**, 7-8.

[24] McCoy, F. (1857). 'On the Foundations of Museum in Victoria', 4, 12. (Goodhugh and Hough: Melbourne.) See also, *Argus*, 29 May 1857 for text of this address.

[25] Pescott, *Collections of a Century*, p. 42. See also Fleming (*this issue*).

[26] Ibid., 35-36.

[27] Sheets-Pyenson, *Cathedrals of Science,* p. 76.

[28] 'Prominent Victorians', *The Leader Supplement*, 28 May 1881. See also *Table Talk*, 9 January 1891.

[29] Handwritten and considerably corrected manuscript in McCoy Papers, Blue Box of miscellaneous loose papers, Museum Victoria Archives.

'THE NATIONAL MUSEUM. - In 'The Book of the Public Library, Museums, and National Gallery of Victoria,' by Mr. E.L. Armstrong, M.A., LL.B., Chief Librarian, recently issued in connection with the jubilee of the foundation of the Melbourne Public Library, will be found some interesting notes of the early history of the National Museum ... Mr. Armstrong acknowledges [Professor McCoy] succeeded, in face of great difficulties, in making the Museum a credit to the colony and a fine memorial of its first Director; and, greatly as it has been improved since his death, the credit of collecting, determining, and describing a large portion of the contents will always belong to its first Director, whose knowledge of natural history was exceptionally wide, besides which he was the possessor of an extraordinarily keen memory.'

From *The Victorian Naturalist*
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Birds, Books and Money: McCoy's Correspondence with John Gould (1857-1876)

Anthea Fleming*

> Zoological museums are either local or general: the first being as complete a series of species as possible of some particular locality; the latter being principally generic types from all parts of the world[1] (McCoy 1856).

Between 1857 and 1870, Professor Frederick McCoy, Director of National Museum of Victoria, acquired for its collection about 5,000 specimens of birds – mainly exotic – from Britain's pre-eminent ornithologist, John Gould, FRS. (This figure is based on the surviving lists and accounts in Museum correspondence. I believe the figure of 10,000 specimens, given by Pescott[2] and others, refers to *all* the specimens supplied by Gould, which included mammals, insects and shells.) Of these, 1,961 birds survive today, of which 561 are mounted, and 1,399 are study skins[3]. One thousand of Gould's skins were originally mounted for display.[4] Apparently some specimens were exchanged with other museums in Australia and elsewhere, but inevitably many fell victims to damage from dust, light and destructive insects.

The National Museum's correspondence files throw an interesting light on the development of the bird collections. Even before McCoy's time, 230 species of Victorian birds were represented[5] apparently donated from private collections. Many birds were – and still are – donated, often with a request for identification, such as the hawk, 'its plumage a beautiful pure white' [White Goshawk] sent by Andrew Anderson of Ballarat (19 February 1868), or the Regent Honeyeater sent by N. Mack from Warrnambool (15 September 1879). But McCoy intended that the Museum should become a general museum, capable of educating the students of the University of Melbourne and the general public about the natural history of all the geographic regions of the world. It was essential to obtain specimens from beyond Victoria and Australia. There were also many exchanges with overseas museums; McCoy was generous with Australian specimens, and often included a pair of Lyrebirds and some Bowerbirds in a shipment of 60 or 100 Victorian birds. Unfortunately only a few lists of what he obtained in this way seem to have survived. Other specimens came in from the Acclimatisation Society, and from collectors and dealers in Australia, New Zealand and beyond.

To obtain the birds for 'a good systematic Zoological Museum,' McCoy wrote to Gould in flattering terms, asking him 'to order ... as complete a set of good bird-skins as can be obtained, and for species [to exemplify] the principal geographic groups, ... for the sum of £400. (Australian specimens of course to be excluded.) ... *All should,* as a *sine qua non,* be named *fully.*' McCoy also ordered the *Supplement* to Gould's *Birds of Australia,* and in a post-script added 'We should particularly have all the strongly marked types – Flamingo, Hornbill, Toucan, Ostrich, Vulture etc.' (14 September 1857).

Gould replied promptly (7 December 1857). 'You shall certainly have a very fine series, as I have the means and believe I have the knowledge, particularly as to their fair value etc. ... You may expect a portion to be sent off to you in a month.' He also offered to obtain quadrupeds, insects, shells and other specimens if required and recommended his publications, such as the *Mammals of Australia,* emphasizing that they should be ordered '*from me direct*'. The publication of his lavish folio works was Gould's principal business and he saw Victoria as a profitable new market. Presumably the cost of Gould's folios and other authors' works led to McCoy's 1859 estimate that one thousand pounds was needed to provide the Museum with its 'books of reference for classification.'[6]

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The first consignment arrived in April 1858, packed in 4 tin-lined cases. It consisted of 1,021 birds, all individually named. Gould directed that they should be unpacked at once and stored in drawers or boxes, away from light and dust. In a fifth box, together with the two parts of the *Supplement* published to date, Gould sent samples of his publications: the *Toucans,* the *Partridges of America,* and sample parts of the *Hummingbirds* and the *Birds of Asia* (Letter, 25 January 1858). 'It will be impossible for you to ascertain the colours of the eyes and the soft parts of your birds when mounting them unless you have these publications.' (The Public Library duly accepted all these books on McCoy's recommendation.[7]) A second shipment of about 400 birds, plus glass eyes for use in mounting the skins, arrived later that year. This had used up the £400, at an 'average cost per bird of just over 5s.6d each' (Gould, 20 May 1858). Gould complained that 'naming the species had been much more work than expected.' This was to be a perennial complaint. 'Many species are ... not available at present. Please say if I should purchase desiderata and say what sum per annum etc. Rarer forms will be more expensive.' In a postscript he asked McCoy to obtain, by loan or purchase, 'one or two eggs of *Menura superba* to figure from', and in due course received one.

In reply to a letter from McCoy (not found, perhaps never entered in the Letter Book), Gould wrote (11 January 1859) that he had sent quadrupeds and birds from parts of Australia outside Victoria and NSW, besides some from Norfolk Island and New Zealand. He suggested that the Museum should have its own copy of the *Mammals of Australia.*

Business between McCoy and Gould settled down for some years into roughly annual shipments of birds, sometimes with nests and eggs and other specimens, and books. Payment was made via Victoria's Colonial Agent General in London. Gould (or his secretary Edwin Prince) drew up a financial statement at the end of each year, and Gould posted it next February.

Nineteenth century discoveries of new fauna in newly explored regions were one result of European exploration and colonial expansion. Alfred Russel Wallace's collections in the East Indies and New Guinea led him to recognize the abrupt boundary (now known as Wallace's Line) between the Oriental and the Australian zoogeographic Regions – which he discussed in 1859[8]. In April that year (14 April 1859) Gould enquired: 'Am I still to collect for you? Fine things from the Aru Islands and New Guinea collected by Mr Wallace fetched high prices – Birds of Paradise five pounds each, the dealers are now re-selling at a profit. May I spend £100 a year for you?' McCoy responded at once. On the 19 June, in a letter briefly summarized in the Letter Book, he gave instructions for the purchase of Wallace's Birds of Paradise. No price limit is mentioned in the summary in the Letter Book.

On 15 February 1860, Gould told McCoy: 'Large collections are now difficult; they contain what you already have.' In his next consignment (arrived April 1861) 'I have sent as much variety as possible, including females to match male Hummingbirds you have.' The only Wallace specimen mentioned was 'a splendid New Guinea swallow (*Dendrochelidon*)'. A pair of *Neomorpha* [Huias] from New Zealand – in high demand because of the different beaks of the two sexes – would now be priceless, as the species was extinct by 1910, probably through over-collecting.

In this letter, Gould showed himself up to the minute with current events, saying that a series of Common Pheasants *Phasianus colchicus*, including 'crosses' and white and pied birds, would 'illustrate Darwin's theory of artificial and "natural selection".' The *Origin of Species* had first appeared only on 22 November 1859. (McCoy's strong disapproval of Darwin's work on 'progressive development' is well-known.) Insects and birds' eggs were also sent. At this stage Gould had £143 in hand and suggested some high-priced birds – 'Surely your rich colony will not be behind the British Museum?' The temptations on offer included *Balaeniceps rex* (the Shoebill) at £20, a new Bird of Paradise *Semioptera wallacei* (Wallace's Standardwing) £14, the extinct *Nestor productus* (Norfolk Island Kaka) '*a large sum* – every year it will become dearer. Tell me if you have *Menura alberti* – I could send a pair. Let me know by return of post.'

McCoy repeated his request for Wallace's material (24 April 1860), apparently in forceful terms. Gould (22 February 1861) replied: 'Many of the birds now sent out were collected by Wallace. Your last note wishing me to *beg borrow* or *steal* anything sent home by him arrived after the present shipment had been forwarded: it matters little as I could not have procured you more ... I am now not only out of funds but you are a little in my debt ...' Such birds as female hummingbirds were difficult to name – a single bird might take an hour, even if he did not have to take it to the British Museum. 'I mention this to show I have some claim on you – if new species should be brought in ... [they] should be sent to me to be figured in my publications... Please support my books...

'And now my friend, let me beg of you to write a little oftener ... whether you get any new birds or quadrupeds ...'

McCoy wrote (24 August 1862) asking again for more of Wallace's birds, and to say that, as Gould had requested, he was forwarding a pair of Victorian Lyrebirds, together with a Chestnut-crowned Babbler and a description and drawings of the Hairy-nosed Wombat from South Australia[9].

On 13 August 1862 Gould wrote to announce the despatch of two cases – 500 fine birds in one, a few more birds and some books in the other. He promised another consignment later, but 'I must now tell you that I have for some time been without funds and you are in debt to me for some portion of the Birds and Books now sent, when convenient let me have a remittance ...'.

McCoy's career as Director was a continuous series of financial struggles with Victorian Governments – he had no notion of confining his expenditure to what the government felt it could afford. In late 1861,[10] he agreed to 'observe the strictest economy ... consistent with the efficiency of [the Museum].' From this time on, Gould was repeatedly irritated by McCoy's lateness with payments.

The expenses of construction of the new National Museum building in the University grounds led to a reduction in McCoy's annual grant, from £2,500 to £1,500 – though his pleas that he was committed to overseas purchases restored it to the larger sum[11].

The books would certainly have added to the debt, as they included a complete bound copy of the *Hummingbirds* and the *Toucans*, apparently sent on approval. But the large case of birds proved an unpleasant shock (25 October 1862):

'You will I am sure regret to hear ... nearly half of [the birds] arrived so full of moth and living larvae that they could not be used and many of them had to be put into the fire at once. The *Colymbus septentrionalis* and *glacialis* [Loons] were the most complete mass of living larvae I ever saw and I think it was from them ... that all the mischief came. The fine *Mycteria senegalensis* [Saddlebill Stork] was full of the larvae ... many others were quite destroyed before their arrival. None of those you were kind enough to send before had the slightest thing the matter with them.

'I hope that by today's mail the Treasurer will send £100 to the order and next mail I hope to send some more. Pray send me ... Wallace and everybody else's rare birds and also his Cuscus and other rare quadrupeds ...'

McCoy had begun this letter with lavish plans to obtain skins of large quadrupeds – beginning with African and Indian Lions, Tiger, deer, bears etc. – to be mounted by the best English taxidermists. Perhaps those that died in English zoos and menageries might be obtained?

Gould (13 May 1863) gave this short shrift as 'not practicable'. Zoo specimens became mangy and emaciated, and in any case the British Museum had first call. The cost of shipping large mounted specimens would be unthinkable. His irritation was well-founded – the Victorian Treasurer had indeed sent him £100 in August, but no second payment had followed, and Gould was now owed £132 and a penny. 'How is this? You really cannot expect large collections to be transmitted if you do not send the means for their purchase.'

He complained that McCoy had not acknowledged the *Hummingbirds* – 'one really ought to be advised of such things. Pray do not become like most colonial men less punctual than you would have been in the "Old Country". Despite the debt, he was sending more birds – 138 specimens – 'Good things are now rare and difficult to obtain – *you have the cream* – still there

are others procurable but you must send me the requisite funds.'

It seems surprising that Gould was prepared to continue to extend credit, even for a comparatively small consignment of birds. However he could not well break off the subscriptions to his costly books, which were his main source of income. Besides, he could not risk losing contact with those who might inform him of novelties or send him specimens.

Ninety-five pounds' worth of birds, and books, including the first two parts of *The Birds of Great Britain* (and some others intended for the Public Library), were sent off in April 1863, but again no remittance was made. On 19 September 1863 Gould wrote: 'Month after month rolls on and I do not receive either a letter or a remittance from you. I know the enervating character of your climate ... but you really ought to favor me with a line oftener ...' Sending the books for all Melbourne subscribers in the same case saved freight costs, but was a fruitful source of confusion as to which institution owed what sum. Subscribers to different works included the Public, University and Parliamentary Libraries.

McCoy's explanation of his current financial problems was written on 25 May 1864. First the 'unexpected expenses' brought about by books sent on approval had caused the cost over-run. Next, 'the Colonial Agent General had paid one of my correspondents about £500 more than I had authorized ... and your additional balance was then left unprovided for, although but for the books it had not arisen. By next mail ... I shall be able to send a remittance...' He complained in turn that the pair of Victorian Lyrebirds which he had sent had never been acknowledged, 'nor the drawings and description which I sent of the new South Australian [Hairy-nosed] Wombat.' From the Lyrebirds, Gould in 1862 had described[12] a new species *Menura victoriae,* (now reduced to a subspecies); it was named for the Queen, not the Colony.

McCoy was able to send £50 in June 1864; 'the remainder would go now, but for a difference of opinion in the Treasurer and Chief Secretary's office.' On 23 July he promised the remaining £32 'by the next mail', but seven months later it was still unpaid.

Gould wrote (24 February 1865): 'Your account has never been balanced since the commencement – a spread of eight years.' He asked for the £32 plus another 17 guineas for books, totalling £49, seventeen shillings and a penny. 'I will then most readily go on and collect all I can for you.' Another case of books was on its way, but clearly there would be no more birds till matters were settled.

McCoy answered that he had already sent £50 in February (25 April 1865), and would have forwarded £25 more but for the breakdown of the mail steamer. 'I have sent to the Treasurer to request that £25 be forwarded ... We have scarcely any Psittacidae of India, Africa and America ... Paradise Birds would be very welcome ...' The £25 was sent in June 1865.

Gould (16 September 1865) was rather annoyed; the draft for £25 had arrived, but could not actually be cashed for another 60 days. But he was sending more birds and books, and announced the publication of his *Handbook to the Birds of Australia* – a summary of the text of his folio volumes. McCoy (24 November 1865) wrote that he would be 'most happy to subscribe to your new book ... and to sound its praise in all quarters'. In fact he had some criticisms, and when in 1869 he came to write a series of articles, under the pen-name Microzoon, in *The Australasian* on 'Our Colonial Birds'[13] (25 September 1869) he summarized them: the lack of measurements, (very useful for identification 'in the hand') and the lack of the 'generic characters', as many readers had no idea 'under what generic head to look'. His articles attempted to remedy this, covering raptors, owls, kingfishers and many passerines.

On 20 December 1865 Gould wrote: 'The £50 received ... in June at last overpaid your long overdue account to the close of 1864 by 2 shillings 11d. Since then I have received £25 and transmitted to you ... a collection of natural history ... to the amount of £65, plus books etc. makes the sum of £74 5s. Among the birds [is] ... an exceedingly rare Penguin *Aptenodytes forsteri* [Emperor Penguin], immature it is true but it is so rare a bird that I never had a specimen in my collection although I

have several times offered £20 for an adult to some of the officers of Ross's Antarctic expedition.

'The Ladies, the Ladies, however have so stripped us of birds for their bonnets that but few are in the market and these of course are high-priced – still if it be your wish I shall go on collecting ... for you until you say *Stop.*' As well as the Emperor Penguin, this shipment included an Andean Condor and many parrots and woodpeckers, plus a few small North American mammals and eggs of about 19 species.

On 24 Aug 1866, Gould complained that McCoy had not yet informed him of its arrival, but offered: 'Some species collected by Wallace in islands north of Australia – not likely to be collected again (Fig. 1). Please say if required with balance of my last account, £49 5s. Let me know of any new discoveries [from] the interior for I am sure much remains to be discovered ...'

McCoy sent the money (26 October 1866), and was 'much obliged to you for putting by some of Wallace's birds ... You have left surprisingly little to be discovered in the bird way in Australia, but I shall be delighted of course to forward any novelties which may occur.'

The next shipment from Gould (26 March 1867) had been 'accumulating for an entire year – 620 species plus Naming took a month of my life. Duplicates cannot be avoided – but where possible I have sent males or females where you had only the opposite sex ... you could exchange duplicates with other Australian museums.' The average price per bird was 5 s – '[this] amounts to £155 which considering the great rise in the price of birds consequent on the present abominable fashion for the decoration of women's hats and bonnets, is exceedingly cheap; and I shall be obliged by your sending me a remittance ... as soon as you can.' This shipment contained no fewer than 50 specimens of birds collected by Wallace. Meanwhile, McCoy had published descriptions of two new species – the Rufous Bristlebird (Fig. 2) and the Yellow-rumped Pardalote *(Annals of Natural History,* 29 Dec 1866[14]) (Fig. 3). (For the controversy with E.P. Ramsay on the name of this Pardalote see K. Hindwood (1950)[15], *The Emu* **49,** 205.) Gould wished to borrow the specimens for the *Supplement.*

Fig. 1. Double-eyed Fig-parrot *Cyclopsitta diophthalma* collected by Alfred Russel Wallace from New Guinea and Mysol Island. Photo by Anne Morton; from the Museum Victoria collection.

'I am even more especially interested with the *Casuarius australis* vel *C. johnsoni* Mueller. Now no-one better than you knows the importance of publishing a good figure ... there are several species of the group ... of which it is impossible to point out the distinctions without an actual comparison, and surely I am the person in Europe who ought to do this.'

Gould's interest had been roused by Ferdinand von Mueller's description of the first specimen of the Australian Cassowary in the *Illustrated Sydney News* (29 December 1866)[16]. The species had been known since the disastrous Kennedy Expedition of 1848, but that specimen had been lost. Mueller named his bird *C. johnsonii* after its collector, and after a detailed description of differences with the well-known East Indian Cassowary wrote:

Fig. 2. Rufous Bristlebird *Sphenura broadbenti* as described by Frederick McCoy (now *Dasyornis broadbenti*). Photo by Anne Morton; from the Museum Victoria collection.

'Further discrepancies ... will unquestionably be pointed out by our learned professor of natural history whenever the solitary specimen, which I intend to present to the Melbourne Zoological Museum, shall have arrived.' But the specimen never appeared. McCoy later suggested to Gould that it had been 'intercepted' (4 February 1868). In a Microzoon article[17] (4 September 1869) McCoy described a young Cassowary 'about two feet long' which had been 'very recently' supplied by Mueller, and compared it with a Cassowary from Ceram of the same size. For this young Australian Cassowary, incidentally, McCoy exchanged a collection of 20 rare Victorian mammal specimens[18], including skins of the Eastern Hare-wallaby *Lagorchestes leporoides* and the White-tipped Sticknest Rat *Hapalotis apicalis* – both now extinct. Mueller also provided a 'portion of the skin of the adult Cassowary'[19] and received in return 'two dozen Victorian birds not found near Melbourne, and one the Red-capped Pomatorhinus [Babbler] only described a few years ago, as a slight exchange for the *Casuarius* with which you enriched the Museum' (26 June 1869).[20]

On 26 June 1867, McCoy sent the Pardalote and Bristlebird to Gould on loan. On 26 September (a letter omitted from Letter Book), he forwarded two specimens of what he believed to be a new Honeyeater *Ptilotis leadbeateri* (Helmeted Honeyeater), named after his able assistant. Gould was dismissive – 'a bird ... long since named *P. cassidix* by Jardine ... I have figured it in the new part of my *Supplement.*' (20 November 1867). In fact McCoy's description was published in the *Annals* on the same day as Gould's in the *Supplement,* 1 December 1867; Jardine's name, as used by Gould, became accepted because it was accompanied by an illustration[21] (Part 2, Plate 6).

Gould thanked McCoy for the loan of the specimens, and said that in the forthcoming part of the *Supplement* he had acknowledged 'McCoy and his Directors' liberality.' He concluded: 'You write and spur me on to collect and send birds to your Museum but you seldom acknowledge their arrival and are somewhat tardy in remitting the money I may have expended for you.' The balance due was £164 10 s – no small sum.

McCoy (4 February 1868) promptly pointed out 'Pray understand that I am the only Director of the Museum of Natural Science here. I have the exclusive management of it as a head of department.' He was disappointed about the Honeyeater (in a Microzoon article[22] McCoy later disputed Jardine's priority and kept the name honoring Leadbeater). 'I beg of you to believe that I have not overlooked the remittance due to you of the £164/10/- through carelessness, but owing to political contest, no payments have been made for 4 or 5 months and cannot probably for two months more – at the same time there is no cause for uneasiness as the Treasury is full of money and all parties willing to pay when political contention is at an end.'

On this occasion the delay in payment was not McCoy's fault. 'During 1867 ... Supply was refused to the Government of the day and money was not available for any of its normal functions.'[23] Moreover, McCoy's grant was reduced by 30% and he was ordered not to incur any further liabilities without the approval of the Chief Secretary.[24]

Gould wrote, announcing another shipment and again requesting this payment on 18 February 1868. He wrote once more on 8 April 1868: 'It is desirable that these accounts should be settled as early as may be, besides which I really want the money.

Fig. 3. Yellow-rumped Pardalote *Pardalotus xanthopyge* described by Frederick McCoy (now Spotted Pardalote *Pardalotus punctatus xanthopyge*). Photo by Anne Morton; from the Museum Victoria collection.

I have put away for you several interesting objects …

'I am sorry you have not yet received the cassowary … I hear there is a specimen en route to London; if so I hope to get a drawing of it.'

On 24 April 1868, McCoy wrote: 'I hoped to have been able to send the remittance by this mail, but although the Treasury is full of money, the contest still remains between the two houses of Parliament – but I hope to be able to send it by the next mail.'

Gould, writing to say that at last he had an Australian Cassowary to draw (19 June 1868), added 'I hope you will send me the money next month.' A fifth part of the *Supplement* was planned 'Pray forward me for figuring any other new birds you may have,' such as Ramsay's new *Orthonyx* (*O. spaldingii*, the Chowchilla).

McCoy, 19 June 1868: 'I exceedingly regret not being able to send you the money by this mail, owing to the political contest between the two houses of Parliament, but shall not fail to do so as soon as the money is available.'

At last on 14 August 1868 McCoy could write: 'I have the pleasure of informing you that by the present mail £115 is forwarded to your credit … the balance I will send by the next mail. Many thanks for your kindness in selecting the additional species for the Museum, which I long very much to receive as I have not seen a bird from you for a long time.' He was able to forward another £63 1s. on 12 October.

On 2 Feb 1869, Gould wrote to tell McCoy that he was sending a case with 530 birds, plus eggs of 15 Indian species. The total cost would be £132 10s. The average cost was between 4 and 5 shillings, though some cost very much more. They included the very rare '*Didunculus strigirostris* believed by many to be allied to the Dodo. I have been blamed for letting it pass out of Europe. [It] should be well cleaned and mounted and if your taxidermist is a clever hand at his profession, he will make it … even better than the one in the British Museum.' [This was the Samoan Tooth-billed Pigeon, now believed to be extinct]. For the future, Gould promised interesting birds from Bogota and a pair of the cave-dwelling Guacharo or Oilbird, *Steatornis caripensis*. 'These will be sent at the close of the present year, unless I hear from you that I must *stop* or that your funds will not allow you to continue.'

This case was duly sent in December 1869, but McCoy did not write to Gould. On the 18 February 1870, Gould wrote:

'Twelve months barring six days have elapsed since I last wrote to you stating that I had a case of Birds and Books for you in the *Yorkshire* and requested to be favored with an answer … On reflection I am sure you will say 'this is too bad!' Your silence really prevents me from acting for you … and is the reason of my sending out … only a small series of birds and a few eggs – only 34 specimens of 22 species.' He also included the parts of the *Birds of Great Britain, The Trogons,* and part 5 of the *Supplement*. 'Besides writing to me I must really ask you for a remittance: your Bill enclosed shows that you owe me £112 14s.'

A major change had occurred. The Government had passed an Act of Parliament (29 December 1869), to provide for 'the incorporation and government of the Public Library, Museums and National Gallery of Victoria.'[25] Fifteen trustees were appointed (4 February 1870), who were given power to make rules and regulations for the corporation. McCoy

had irrevocably lost his independence. In his rearguard struggles to protect the Museum he had built up, he had no time to write to Gould. Many of his orders for overseas material had to be cancelled at this period. Moreover, in 1871, changes to the Museum's finances meant that many payments, including salaries, were delayed for months because such business now had to go, via innumerable official forms, through the President of the Trustees.[26]

Gould wrote (25 February 1871) 'As I have not received a reply to my Letter ... of Feb 12, 1869 nor to that of Feb 18, 1870, I am naturally very desirous of knowing the reason of your silence ... What can be the cause of your not replying? Our correspondence is mainly in your interest and I do think that on reflection you will come to the conclusion that you are not using me well ... The debt of your Museum is increasing ... it now owes me £119 ...

'I shall not in this allude to the subject in which we are both interested – natural history – but am ready to enter upon it when I again hear from you.'

At last McCoy replied: (c. 18 May 1871): 'The delay in settling your account and in writing to you arises from the unsettling the affairs of the Museum by the appointment of Trustees for it and several allied institutions who so reduced and impeded all money transactions that I must beg you to forward nothing more until I am able to place your money in your hands. I have made an application to have your £119 paid forthwith, but cannot be certain when it will be forwarded as yet. I shall stop all expenditure for the present until matters are more settled.' In June, McCoy apologized for further delay – Gould's bill must be sent in the form requested by the trustees.

On 25 October 1871, Gould replied: 'In your letter ... you say that the change in your Ministry has delayed the remittances due to me ... I have received no money from you since the early part of 1869 and therefore I hope the Trustees will take my claim of £119 into consideration ...

'I particularly regret that the action of the Trustees has prevented you from continuing your collection as you have thereby lost many very fine things from New Guinea and the neighbouring islands ... you I know will also regret this. To be cramped in your endeavours to raise a large and fine collection for the Colony must be very disheartening.

'A short time since I delivered to Mr Bain of the Haymarket London the two parts of the *Birds of Great Britain* due to your Museum and they will be duly delivered to you by his correspondent in Melbourne on their arrival.' Apparently Gould had handed over the distribution of his books to Bain. The bill is annotated: Paid by mail 21/12/71.

McCoy wrote on 27 December that year, apparently believing that all was well, now that the bill had been paid: 'Pray keep at least 25 pounds' worth of desiderata for us a year until good times come again,' and again in 15 July 1873: 'I forward by the mail £20 on a/c of books etc. and hope to hear you will continue your kind vigilance for new or rare species not formerly sent, as the tremendous dislocation produced by putting the Museum in connection with a body of Trustees is settling down more near its good old way.' But apparently Gould did not respond to this suggestion.

Gould's last letter (15 April 1876) refers to a shipment of books forwarded by Mr Bain. It shows clearly that he could no longer disguise his exasperation with disorganized subscribers.

'Kindly say for Heavens' sake to whom the case should be shipped and to which library *New Guinea* should be sent. This confusion sadly perplexes me and makes me say I will never send another book to Melbourne ... Let your secretary find to which Institution the other books should be forwarded to, if possible by return of post and you shall have the continuation of *New Guinea*. Pt 3 is ready containing some marvellously beautiful things; this and some fine birds shall at once be sent when I hear from you.

'This New Guinea is a wonderful country teeming with novelties, novelties which bear so much upon Australia as to render it of great interest to you.

'Pray then get me out of this mess with regard to names and payments of your Melbourne Institutions, and you shall have all early information on the subject.'

McCoy could no longer order birds without the Trustees' approval, so it seems nothing came of this last offer on Gould's

part. Gould's signature now looks very shaky, unlike his former confident bold hand: it clearly shows that he was already affected by ill-health. Gould was by now 71 years old; he was to die five years later on 3 February 1881. Professor McCoy was to continue as Director of the Museum, despite all difficulties, until his own death in 1899.

N.B. No attempt has been made to modernise obsolete scientific names. Where possible, common names have been inserted.

All correspondence quoted is held in the Library of Museum Victoria. The inward letters of Gould and others are quoted from the originals. McCoy's letters are taken from the Museum's Letter Books – unfortunately, often only a brief summary is recorded, and some letters were never recorded at all. Gould methodically quotes dates of letters received from McCoy, so some gaps can be identified.

Gould's letters, 30 in all, with accounts and lists of specimens supplied, are generally in good condition, though some thin paper is becoming brittle. Some letters, originally posted without envelopes, have suffered tearing, with loss of some text, when their stamps were removed by some unknown stamp collector.

Acknowledgements
My sincere thanks are due to Frank Job, Wayne Longmore and Alan Yen of Museum Victoria, to Doug McCann who kindly supplied copies of McCoy's 'Microzoon' articles, to Merilyn Grey and Anne Morton of FNCV, and to my husband and son for technical assistance. Finally, I must remember the encouragement given by the late Allen McEvey to my early interest in Gould and his works.

Notes

[1] Pescott (1954), *Collections of a century*, 28.
[2] Pescott (1954), 42.
[3] Wayne Longmore, *pers. comm.*
[4] Pescott (1954), 42.
[5] Pescott (1954), 7.
[6] Pescott (1954), 44.
[7] A. Tulk, Librarian, Museum Victoria correspondence, 13 May 1858.
[8] Wallace (1859).
[9] Datta (1997), 432.
[10] Pescott (1954), 47.
[11] Pescott (1954), 53.
[12] *Proceedings of the Zoological Society of London*, 1862, 23, cited by Whittell (1954), 295.
[13] Microzoon (McCoy) *Australasian*, September 25 1869, 390-391.
[14] Cited by Whittell (1954), 461.
[15] Hindwood (1950).
[16] F. von Mueller (1866).
[17] 'Microzoon' (McCoy) (1869a).
[18] McCoy, letter to F. von Mueller, 9 February, 1869, Museum of Victoria correspondence.
[19] McCoy, letter to F. von Mueller, 28 May 1869.
[20] McCoy, letter to F. von Mueller, 26 June 1869.
[21] Mathews (1923). 'Birds of Australia', vol. 11, 504.
[22] 'Microzoon' (McCoy) (1870).
[23] Pescott (1954), 65.
[24] Pescott (1954), 88.
[25] Pescott (1954), 69.
[26] Pescott (1954), 74.

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McCoy, at that time working as Sedgwick's assistant, was given the task. The geological paths of McCoy and Clarke crossed for the first time.

McCoy (M'Coy 1847) soon published the results of his classification of the fossils. He recognised 'abundant fossil remains of animals referable to the palaeozoic period', and above these 'a series of clays, shales and sandstones, with remains of fossil plants and beds of coal'. The genus *Glossopteris* (Fig. 1) was one of the most common plant fossils that he recognised, and he argued that it was 'never found in the old-coal fields, but well known in coal-beds of the oolitic age in various parts of the world'. *Glossopteris* had been described and named by Brongniart in 1828 in material collected from the Newcastle Coal Measures in New South Wales by Robert Brown, Matthew Flinders' botanist, in 1801 or 1802 (see Brown 1946; Murray 1983; Vallance 1975). *Glossopteris* was found in coal from India as well as from Australia by Brongniart, but was quite unknown in the European coal measures (Vallance 1975).

One of the new plant fossils named by McCoy was *Cyclopteris? angustifolia*, a species that received more of his attention in later years. At the 17th *Meeting of the British Association for the Advancement of Science* in 1847, he discussed Clarke's 'oolitic' plant fossils and stated that no trace existed of 'any characteristic fossil of the old coal of Europe or America' (M'Coy 1848). These 'old coals' were considered to be of Carboniferous age.

Convicts first found coal on the coast north of Sydney in 1791. George Bass, the explorer, had observed coal cropping out along the coastal cliffs as he sailed both northwards and southwards from Sydney during 1797 (Vallance 1975). Bass speculated upon the possibility of a coal basin in the region. At that time, 'Lithological stratigraphy still prevailed and insofar as anyone cared about Australian coal it was assumed to match European (Carboniferous) coal' (Vallance 1981).

The accumulation of knowledge relating to the age of Australian coal has been documented by Archbold (1985), Branagan (1998), Brown (1946), Murray (1983), and Vallance (1975, 1978, 1981). Prominent

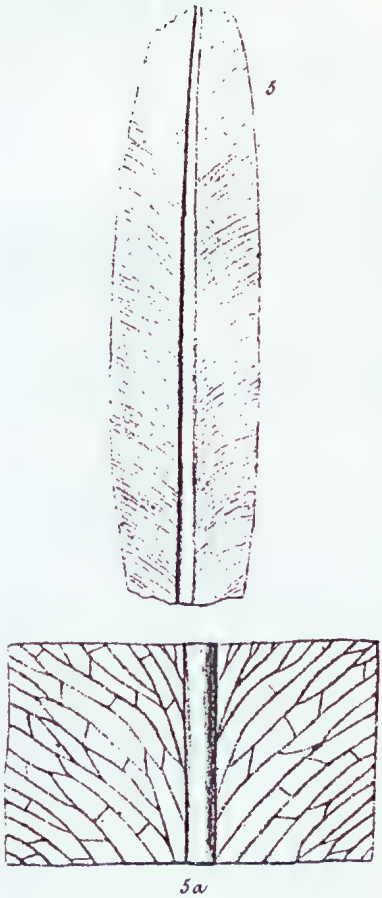

Fig. 1. *Glossopteris linearis* (M'Coy) from M'Coy (1847) Plate 9; 5 and 5a.

participants in this gathering of knowledge were T.L. Mitchell, P.E. de Strzelecki, J.D. Dana, J.B. Jukes, W.S. Macleay, F.W.L. Leichhardt, A.R.C. Selwyn, R. Daintree, and of course McCoy and Clarke. Opinions expressed varied as to the age of the coals and as to whether or not the coal plant fossils were conformable with associated marine invertebrate fossils.

McCoy's 1847 paper classifying Clarke's fossils (M'Coy 1847) polarized the geological community when he confidently argued for a Mesozoic age for Australian black coals. By 1847, Clarke had moved on from his 1841 belief that the coals were Oolitic. Based upon fossil evidence, J.B. Jukes, in 1842, had decided that "Australian coal was at least as old, and

McCoy and Clarke: their Dispute Over the Age of Australia's Black Coal

Roger Pierson[1]

Abstract
From 1847 until his death in 1899, Professor Frederick McCoy, palaeontologist in Melbourne, maintained a war of words in the scientific literature with Rev. William Clarke, geologist in Sydney, concerning the age of Australia's black coal deposits. McCoy was convinced that the coals were all of Mesozoic age and Clarke, during the period from 1847 to his death in 1878, maintained equally vehemently that they were Palaeozoic. In fact, Clarke was correct in placing the New South Wales coals in the Palaeozoic, and McCoy's placing of the Victorian coals in the Mesozoic was also correct. The two men were both particularly stubborn and neither would admit that they might have been arguing about coals of differing ages. Both stood unbendingly by their Northern Hemisphere, European backgrounds, and neither would change their views in the face of new evidence from the Colonies. (*The Victorian Naturalist* **118** (5), 2001, 219-225.)

For over 30 years from the middle of the 19th century, Frederick McCoy and William Branwhite Clarke conducted wordy battles in the scientific literature over a matter dear to both their hearts: the age of Australia's black coal beds. McCoy argued from Melbourne for a Mesozoic age, while Clarke in Sydney argued equally strongly for a Palaeozoic age for the coals. It is interesting to note that although Clarke maintained his belief in a Palaeozoic coal age for most of his time in Australia, he argued for an Oolitic age in 1841 (Jervis 1944; Vallance 1975; Vallance 1981). The Oolitic (or oolitic as it was commonly written) of the 1840s was approximately equivalent to the Jurassic Period of the Mesozoic Era in modern terminology. Explaining the prevailing view on coal held in the mid-1800s, Stafford (1989) wrote, 'Since Carboniferous coals were considered of higher value as steam fuel, this stratigraphic battle had direct implications for colonial development'. As well as a clash of intellects between McCoy and Clarke, there was an underlying commercial pressure on them to assert that the New South Wales coals were Palaeozoic in age. The Palaeozoic 'Carboniferous' age of the time was that proposed by Conybeare and Phillips in 1822 (Secord 1986). It spanned what are now accepted as the Carboniferous and Permian Periods.

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Frederick McCoy's early life is covered elsewhere in this volume. William Clarke was born in East Suffolk, England in 1798 (Grainger 1982). His formal education was completed at Cambridge University where one of his tutors was Rev. Adam Sedgwick, Woodwardian Professor of Geology. Clarke obtained his BA degree in 1821 and his MA in 1823, and he was ordained in the same year. He was accepted as a Fellow of the Geological Society of London in 1826 (Mozley 1969). Clarke combined his curate's duties with poetry writing and the practice of geology. In 1828 his presumed first geological publication, in the *Magazine of Natural History*, described how he replaced a wooden handle on his geological hammer with 'an elastic handle of leather' (see Grainger 1982). Following severe attacks of rheumatism, he received medical advice that he should live permanently in a warm climate. This advice, together with his curiosity concerning the unknown geology of the colonies, led Clarke to emigrate to New South Wales with his family in 1839 to take up a chaplaincy.

Clarke continued geologising and collecting around New South Wales as he undertook his church ministry, just as had been his practice in England. He sent several boxes of fossils from New South Wales to Professor Sedgwick at the Woodwardian Museum in 1844, for classification. Sedgwick did not consider himself a palaeontologist and the fossils remained unclassified until 1847 when Frederick

probably older than, the Carboniferous coal of England' (see Vallance 1981). Clarke adopted this position and maintained it for the remainder of his life. Since McCoy and Clarke were prominent proponents of the ensuing Mesozoic/Palaeozoic coal age furore in Australia, their publicly aired differences dominate this paper.

In 1848, Clarke had sent a specimen to Sedgwick that bore impressions of *Glossopteris* along with marine invertebrate remains (Vallance 1981). This was evidence of the co-existence of a plant fossil that McCoy was convinced was Mesozoic with Carboniferous invertebrate fossils. McCoy remained silent, and amazingly Clarke did not press the issue.

McCoy was chosen as the first Professor of Natural History of the University of Melbourne when it opened in 1855. His arguments with Clarke gathered momentum.

In 1860, the Governor of Victoria and President of the Royal Society of Victoria, Sir Henry Barkly (1861) reported to a Royal Society of Victoria meeting that specimens of the fossil plant genus *Taeniopteris*, discovered in coal beds at Cape Paterson, had been exhibited at the meeting by Professor McCoy. McCoy had told the meeting of Clarke's claim that an absence of *Taeniopteris* in Australian coals indicated that they could not be of Oolitic age. With this new species, *Taeniopteris daintreei*, McCoy felt he had strengthened his Mesozoic age position for the coal and refuted Clarke's claim (Fig. 2). (In fact, the coals at Cape Paterson are Mesozoic, and McCoy was correct in his assumption of that age based upon the fossil *Taeniopteris daintreei*.)

Clarke (1861a) was quick to respond to McCoy's assertions and wrote that, '*Taeniopteris* and *Glossopteris* (*Sagenopteris*) have been the means of placing, by some geologists, the coal deposits of Australia and India in the horizon of the oolitic coal'. He pointed out that the genus *Taeniopteris* may range from Carboniferous to Tertiary and that the age was determined by the species. Clarke then returned to McCoy's original classification of his fossils in 1847. He wrote, 'Mr McCoy, who knew nothing of Australian plants' had 'because of the absence of certain genera, and the presence of others

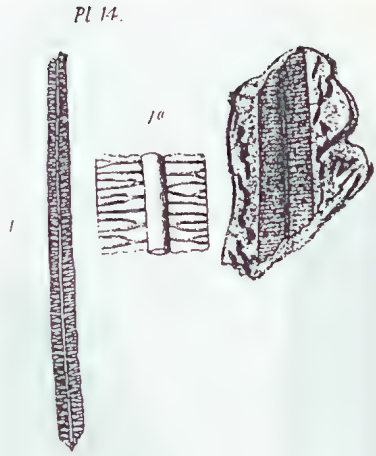

Fig. 2. *Taeniopteris daintreei* (McCoy) from McCoy (1875) Plate 14; 1, 1a and 2.

which have a relation to some oolitic species' assumed an Oolitic age for the fossils he had sent to Sedgwick in 1844. Clarke maintained, in this paper, that the coal beds were Carboniferous.

McCoy (1861a) immediately took exception to Clarke's comments. He stated 'that the time of a scientific man may be better employed in endeavouring to add new facts to the general store of human knowledge than in defending himself or his views...'. But in this case he felt he had to respond, and in doing so he dissected Clarke's paper paragraph by paragraph, fighting for acceptance of his own age interpretation and strongly dismissing Clarke's Palaeozoic age for the plant fossils. McCoy accused Clarke of misrepresenting the source of a specimen of *Lepidodendron* found by 'an unscientific friend' from Queensland. In this paper, McCoy named a new genus, *Gangamopteris*, through a specimen he called *Gangamopteris angustifolia* (Fig. 3). The example was from Bacchus Marsh sandstone. He stated that he had previously figured it from the New South Wales coal beds under the name of *Cyclopteris? angustifolia* in 1847. He inferred its age to be Mesozoic because of its association with *Glossopteris*.

In his turn, Clarke (1861b) responded to McCoy's dissection of his paper. He stated that he was 'not aware, till I perused

Fig. 3. *Gangamopteris angustifolia* (McCoy) from McCoy (1875) Plate 12; 1: Plate 13; 2 and 2a.

Professor McCoy's "Commentary" on my letter, that I had offered any grounds of offence in it'. He took McCoy's paper apart, again paragraph by paragraph, and proceeded to justify his belief that Australia's coal bearing rocks were Carboniferous. On the question of the *Lepidodendron*, he corrected McCoy and stated that 'the late Dr Leichhardt, an excellent geologist', had recognised the fossil in New South Wales. The ill will between the two men was evident in almost every sentence of their papers, despite Clarke writing 'I have no object in any controversy on this question but truth'.

The bickering continued when McCoy (1861b) informed the reader of the 'real point at issue, namely:– Mr Clarke holds and has always held that the "*Glossopteris* beds" associated with the coal of New South Wales are Palaeozoic, and belong to the same geological epoch as the underlying marine beds containing Lower Carboniferous animal remains. I hold and have always held that the aforesaid "*Glossopteris* beds" are Mesozoic'.

In a paper read to the Royal Society of Victoria in 1861 but not published until 1865, Clarke (1865a) argued at length for a Palaeozoic age to be assigned to the coal beds of the Maitland district of New South Wales. He maintained that he had located beds 'containing fossils of the same Palaeozoic formation which Professor M'Coy has long ago determined to be at the base of the "Lower Carboniferous" formation of Ireland' at Maitland.

In the same year Clarke (1865b) continued to press his opinion against McCoy's Oolitic age for the New South Wales coals. He wrote, 'the vegetable fossils, which are taken as the datum for the Oolitic age of the coal, have been traced into a position between rocks assigned, from their distinctive zoological fossils, to be as low as the "base" of the old "Carboniferous system"'. He defended his stance in relation to the existence of Mesozoic formations in Australia by stating that, 'the existence of Mesozoic formations has not been disputed by me; all that my position amounts to is the denial that the coal beds of New South Wales are Oolitic'. Clarke (1861c; 1861d), described *Glossopteris* and *Cyclopteris* in shale at Maitland lying **beneath** beds containing Palaeozoic marine fossils, reinforcing again his Palaeozoic age for the associated coal.

The Australian geological community must have been getting thoroughly tired of the sparring between McCoy and Clarke that was interminably ongoing through the respected journal of the Royal Society of Victoria. In reality the two individuals allowed their respectively entrenched posi-

tions to outweigh their intellects. McCoy and Clarke met on at least one occasion. Clarke (1861a) wrote that he had personally shown McCoy plant fossils that he had taken to Melbourne. Taking into account the obvious hostility they showed towards each other in their writing, it would be interesting to know how McCoy and Clarke reacted towards one another at this meeting. Vallance (1978) felt that both McCoy and Clarke were 'locked in a cell of European experience', and that 'McCoy remained a British palaeontologist in Australia, just as Clarke continued to be a British geologist'.

In another paper read to the Royal Society of Victoria in 1861 and unpublished until 1865, McCoy (M'Coy 1865a) reported on the age of fossils collected at Wollumbilla, on the Fitzroy Downs of Western Australia, and sent to him by Clarke. (Despite the animosity between the two, Clarke continued to rely on McCoy's palaeontological skills.) McCoy stated that, for the first time in Australia, he had found a Mesozoic marine fauna, including ammonites and belemnites in this collection. He felt that the marine deposit was of exactly the same age as the eastern coal beds; 'to the base of the Mesozoic series, certainly not lower than the Trias, and not higher, I think, than the lower part of the great Oolite'.

At his Presidential Anniversary Address to the Royal Society of Victoria in 1864, McCoy (M'Coy 1865b) noted that Richard Daintree had 'tried to settle the points in dispute between Rev. Mr. Clarke and myself, relative to the age and position of the beds associated with the coal of New South Wales, but failed'. Richard Daintree (1864a; 1864b) had, in fact, detailed at length his belief in Clarke's observation of *Glossopteris* in shales and coal below the marine Carboniferous beds at Stony Creek, near Maitland. Daintree (1864c) repeated his support of Clarke's position in a brief abstract printed in the *Bulletin de la Société Géologique de France*. Interestingly, this abstract figured a measured stratigraphical section at Maitland, clearly showing *Glossopteris* beds below the then undisputedly Carboniferous marine beds. It is difficult to understand how McCoy interpreted Daintree's reports as having failed to 'settle points in dispute'. In 1864, William Keene (1865), Examiner of Coal-fields, New South Wales, reported that '... *Glossopteris* accompanies the entire series of Coal-measures from the topmost to the lowest seam'. He stated that his specimens 'will prove satisfactorily that the coal-seams of New South Wales belong to as old a geological series as those of Europe'. (His statement did not prove to be correct.)

McCoy (1867) took his Mesozoic coal age argument to the Americans with a paper in *The American Journal of Science and Arts*. In the same year, he (M'Coy 1867) published his belief in the age of Australia's coals in the *Annals and Magazine of Natural History* in England; he had published his descriptions of Clarke's original fossils in this journal in 1847. He referred to species of *Zamites* and *Taeniopteris* recognised from Cape Paterson and Bellarine, *Glossopteris* and Belemnites and Ammonites from New South Wales, and *Gangamopteris* from Victoria and New South Wales, as positive proof for a Mesozoic coal age.

Clarke (1868) also published in *The American Journal of Science and Arts*. Referring to the New South Wales coal seams, he stated, 'Up to a comparatively recent period, it was not known that under the marine beds below these coal seams, other seams occur bearing the same genera of plants as in the upper beds'. Daintree, he maintained, had verified this fact.

In his *Prodromus of the Palaeontology of Victoria*, McCoy (1875) described and provided plates of Victorian examples of three species of *Gangamopteris* from Bacchus Marsh and one of *Taeniopteris* from Cape Paterson. He maintained that their age was Mesozoic. The plates and descriptions for the *Prodromus* had been prepared in the 1860s, but publication was delayed due to a lack of government funding until 1875.

In his *Report on Palaeontology of the Geological Survey for the year 1891*, McCoy (1892) described a fragment of *Schizoneura*, 'from a newly discovered bed just under the famous *Gangamopteris* sandstone of Bacchus Marsh'. This fossil, he wrote, indicated a Mesozoic (Triassic) age for the bed. Although the precise loca-

tion of the supposed Triassic bed was not given, and McCoy mistakenly placed it **below** the *Gangamopteris* beds, the *Schizoneura* was probably discovered in what is now known as the Council Trench Triassic outcrop at Tramway Lane, Bacchus Marsh. The outcrop is stratigraphically **above** the *Gangamopteris* sandstone. McCoy (1898) reported the finding of *Taeniopteris sweeti* in 1897 at Bacchus Marsh in the same sandstone beds as *Gangamopteris angustifolia* and found it 'of value as indicating a Mesozoic age for this Victorian rock'.

Clarke had died, aged 80 years, in 1878. In that year he (Clarke 1878) published the fourth edition of his book *Remarks on the Sedimentary Formations of New South Wales* in which he remained adamant that the New South Wales coal beds were of Palaeozoic age.

From 1847, to his death in 1899, Frederick McCoy always maintained that the plant fossils found in Australian black coal beds and identical fossils found in other, non coal-containing beds, clearly and unerringly indicated that the coal and sediments were all of Mesozoic age. He stubbornly refused to bend in the hope that he would ultimately be proved correct.

In presenting a lecture on early Australian geologists, Professor E. Skeats (1933) wrote of McCoy stating, 'He was, in fact, a distinguished palaeontologist, rather than a geologist. There is, I believe, no record of his ever having undertaken fieldwork'. This is generally true of McCoy's time in Australia; he had, however, carried out geological field survey work in Ireland in the 1840s (Anon 1899; Anon 1900) and with Adam Sedgwick in Wales in the early 1850s (Secord 1986). Clarke's geological work, in contrast, was based upon numerous collecting journeys to the field and upon his observations made there. Perhaps it was inevitable that two men with such differing approaches to their science should have vigorously defended such opposing views on the age of Australia's coal beds.

As Darragh (1992) reasoned, 'Neither McCoy nor Clarke realised that they were arguing about two different series of rocks of widely different ages. In the end McCoy was right about the Mesozoic age of the Victorian coal bearing rocks, and Clarke was right to regard those of New South Wales as Palaeozoic. Both scientists did not come out of this controversy very well, because neither was prepared to accept the new evidence of the other but argued from a predetermined position based on outdated data'.

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Frederick McCoy's Anti-evolutionism – the Cultural Context of Scientific Belief

Barry W. Butcher[1]

June 1865 and excited Melbournians are flocking to the National Museum of Victoria to see the latest arrival, a gorilla, the first (albeit stuffed) to arrive in the Antipodes. Centrepiece of a glass-encased 'family' of great apes, it represents the successful culmination of the Museum Director's three-year effort to acquire a specimen of this the largest and most recently 'discovered' of the anthropoids (Butcher 1988; Fig. 1). Nearly a century and a half later we can only speculate on the reasons why attendance at the museum doubled in the weeks after the first appearance of *Gorilla gorilla* in the booming post-goldrush metropolis of Melbourne. Were they expecting to see a ghastly human alter ego, a monstrous, degraded creature, human-like but manifestly not human, embodying perhaps all the worst features of humanity, all the vices and none of the virtues? Or were they there to see and be impressed by humanity's most recently discovered long lost relative?

Of course we can never definitively answer the question; these first Australian viewers of the gorilla stand as far apart from us culturally and historically as we do biologically from the poor grinning creature in the glass case does. We do know however what first drew them in such large numbers – a letter from the Museum Director himself, Frederick McCoy, published in the local newspaper, the *Argus*. It was a letter of exhortation, calling on Melbournians to come and see the new arrival so as to adjudge for themselves.

> ... how infinitely remote the creature is from humanity, and how monstrously writers have exaggerated the points of resemblance when endeavoring to show that man is only one phase in the gradual transmutation of animals, which they assume may be brought about by external influences and which they rashly assert is proved by the intermediary character of the gorilla between the other quadramana and man (*Argus* 1865).

No clearer statement of disbelief in 'the development hypothesis' is likely to be found in the first years after the publication of Charles Darwin's *Origin of Species* in 1859. That McCoy detested evolutionary theory is clearly the case, but the battle over 'Man's Place in Nature', sparked off by Thomas Henry Huxley's book of the same name, provided the first opportunity in Australia for public discussion of Darwinism and its implications for both science and society. McCoy's letter was as much a shot in this battle – aimed clearly at Huxley and his supporters – as it was a promotional piece for the Museum.

But to say that McCoy was anti-Darwinian is in fact to say very little; an earlier historiography of science, viewing the 'Darwinian revolution' through post-Darwinian eyes, would have dismissed his position as that of an outdated scientist, a doomed representative of an earlier age of science when Natural Theology held sway. But this approach will not do anymore; thirty years of careful scholarship have shown just how complex the issues surrounding this debate over evolution really were. Perhaps the first intimations of this complexity came in the groundbreaking work of Robert Young in the early 1970s, when Darwinian scholars were reminded that ideas draw their importance from the specific social and intellectual contexts in which they originate and that their origin is itself the product of multiple cultural resources. Since then Adrian Desmond has brilliantly dissected 'the politics of evolution', demonstrating how social structure and class interest played a role in the myriad ways in which pre-Darwinian evolutionary theories were used in political and social debate, while James Moore and James Secord have built on Young's work to show again how cultural resources are utilised and in turn utilise scientific theory

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Fig. 1. The gorillas at the museum. A wood engraving by Samuel Calvert 1865. La Trobe Picture Collection, State Library of Victoria.

and practice. Simple stories of winners and losers in the development of science no longer cut the mustard (Young 1985; Desmond 1989; Desmond and Moore 1991; Secord 2000).

What I wish to do in this paper is to briefly look again at McCoy in the context of his scientific, social and cultural background. I want to suggest, albeit speculatively, that rather than his rejection of evolutionary theory being out of step with his scientific career it sits easily with his roles as geologist, Museum Director and Colonial scientific spokesman. I am not suggesting that there is full consistency in his position, only that it makes his involvement in a particular mid-Victorian Colonial cultural setting more interesting, more complex and more historically fascinating.

Learning his trade

As James Secord and contributors to this volume have shown, McCoy owed his geological training to two patrons who just happened to be giants of nineteenth-century British science – Roderick Murchison and Adam Sedgwick (Secord 1986). While both were opposed to evolutionary theory of any kind, it was Sedgwick who most

stridently spoke out against it. In his massive critical review of Robert Chambers *Vestiges of the Natural History of Creation*, written in 1845, a year before McCoy became his assistant, he thundered against a theory of cosmological evolution that was factually inaccurate, based on a poor philosophy of science and most crucially that 'annulled all distinction between physical and moral' and reduced human reason to nothing more than a development of animal instinct (Secord 2000: 245). Sedgwick was an evangelical Anglican, seeing in science not only the possibility of producing greater material wealth, but a moral trope that justified religion and the social order. McCoy moved from being an Irish Catholic, with all the social and professional disadvantages that entailed in mid-century Britain, to High Anglicanism. When in his later career in Australia he took up arms against the more dangerous evolutionary theory espoused by Darwin and championed by Huxley, Sedgwick's rhetoric still seemed to be ringing in his ears. In the meantime, however, he needed a job; according to Secord, his early work was not highly thought of in British scientific circles and his involvement in a long and bitter geological spat between his former and current patrons placed him in a difficult position. When Australia beckoned, both Murchison and Sedgwick came to the party and supported him for the Chair of Natural History at the University of Melbourne (Secord 1986; Wilkinson *this issue*). It was a decision that almost certainly saved his career; his contemporary James Salter, considered by many the better geologist, struggled on in near penury in a Britain where good positions in science were almost impossible to find, before finally conceding defeat and throwing himself into the Thames. For McCoy, the future might lie in a colony half a world away but it paid well and eventually led to honours he could never have expected had he stayed in the metropolitan centre, among them a knighthood, and perhaps the best of all, an FRS. When he left Britain in 1854 he took with him a goodly number of professional debts, to Sedgwick in particular. And as I implied above, among these was an aversion to evolutionary theory. At one level his sorties against evolution can be seen as repaying some of those debts; he could bring credit to his patrons by opposing theories which defied the religious, social and scientific outlook which they had done so much to foster. As it turned out, in Melbourne he found an establishment elite largely attuned to hear that message.

Going public against evolution: the social context of a scientist's actions

McCoy's involvement in the 'gorilla war' in Melbourne in the early 1860s was largely confined to offering material ammunition – anatomical specimens from the Museum and ultimately the gorilla itself. Statements of support came only within the confines of scientific meetings, especially the Royal Society of Victoria. In a sense this is a case of presenting credentials, demonstrating support for the dominant establishment view. And here 'establishment' encompasses both the scientific community and the political and religious elites in the colony – the presence and involvement of the Victorian Governor Henry Barkly, Anglican Bishop Charles Perry and the prominent Roman Catholic John Bleasdale on the side of those opposing evolution ensured that an official line would emerge and be clearly identified for public consumption in the press (Butcher 1988).

In 1869 and 1870 when McCoy presented his most celebrated public protest against evolution he did so in a forum where the same establishment interests were to the fore. The Early Closing Association had its origins in the concern of prominent Melbourne citizens to counter the rise of anti-religious and free-thinking groups; local businesses were encouraged to close for a period on one day of each week in order to allow workers to attend lectures on political, religious and scientific subjects. By then McCoy was an important figure in the social and scientific fabric of the colony, his scientific orthodoxy, as defined by establishment interests, unimpeachable. With that bastion of respectability, judge Sir Redmond Barry in the Chair, he prefaced his first lecture with the comment that in a previous talk he had been criticised for saying that '... the highest scientific authorities with whom he was

personally acquainted were among the most humble-minded believers of the great religious truths that could be found in any part of the community' (McCoy 1870: 1). Thus at the outset, his audience was left in no doubt about the relationship between true science and true religion. The great figures of science – Sedgwick and Murchison pre-eminently – provided proof that the two could, indeed must, be held together. The lecture itself simply reinforced the message, with an account of the Biblical story of creation rendered in the light of modern science, and reiteration of the message that science rightly understood was an invaluable aid to religion. For the body of his criticism of evolutionary theory he drew on Sedgwick's earlier attack on *Vestiges,* bolstered by his own observations in Australia. To account for the geographical distribution of animals and plants he turned to the 'centres of creation' theory of the Swiss-American zoologist Louis Agassiz whereby the flora and fauna of the world could be divided into six zoological provinces in both hemispheres. Each province had its own autochthonous life forms that had been created for the particular conditions existent at the time. Similarities between groups of animals and plants that were often geographically distant were explained not by recourse to any genetic relationship but as the working out of a divine plan. Discussing the idea of such provinces McCoy used the examples of the Ostrich, Rhea and Emu to show that similarity of form and habit could not be assumed to mean common ancestry, for

> ... there could be no question of one of these forms having grown out of the other by a difference in surroundings for the ostrich has two toes, and the Australian and South American forms three – a change not required and all three thriving when introduced into any one of the localities by man (McCoy 1870).

At the level of the particular such as this case epitomises, McCoy showed little regard for Darwinism, giving some support to the claim that he may never have read the *Origin of Species*. It is doubtful that had he done so he would have changed his view – what was to be deplored was 'the development hypothesis' itself which, whatever the mechanism underlying it, would not fit either his science, his religion or the traditional values he drew from both. He was Sedgwickian in outlook through and through. But a more provocative claim might be made which gives a fascinating twist to the story; McCoy was a geologist, and as Darwin himself admitted, geology offered little immediate support for the theory of evolution. McCoy's stance then was, even in 'scientific' terms, a reasonable one. As Susan Sheets-Pyenson points out in her study of nineteenth-century museums, other palaeontologists given the task of building up these 'cathedrals of science', such as Hermann Burmeister in Argentina and William Dawson in Canada, also treated evolution with suspicion (Sheets-Pyenson 1988). Rather than being a scientific eccentric then, McCoy fitted a pattern; and when one adds to Sheets-Pyenson's list McCoy's opposite number in Sydney, Simon Pittard, this claim gathers further strength.

In his old age McCoy complained that he had not been provided with enough money to organise the museum according to his acceptance of Agassiz's theory of 'centres of creation' (McCoy papers 1898).

The University – a centre of anti-Darwinism?

The Australian physicist William Sutherland complained that when he attended McCoy's lectures at the University of Melbourne in the 1870s he was constantly subjected to anti-Darwinian sentiment as McCoy 'thundered against' evolutionary theory. Worse, examination papers were laced with questions requiring students to critique evolutionary theory (Osborne 1920).

Was this all simply an obstinate rejection of a naturalistic theory that was rapidly overtaking his own providential philosophy of science? At one level it was certainly a rejection of that theory, but this was just one side of the coin. For forty years McCoy had worked tirelessly to uncover the secret of Australia's geological past; if his early work in Britain had indeed been poorly thought of, his Australian work was groundbreaking and original, as other papers in this volume show. Rejection of a given theory then, did not determine the quality of the work done.

Discussion and Conclusion

Towards the end of his life McCoy was showered with honours; a knighthood in 1891, an imperial award he could hardly have dreamed of when he left for Australia in 1854, and of even greater significance for understanding his scientific career, admitted to Fellowship of the Royal Society of London. The Irish Catholic turned Anglican had now entered into the highest realms of the social and scientific establishment. His achievements recognised by a scientific community that no longer shared his understanding of science rewarded him for his contribution to the understanding of Australia's paleontological history. What then did his anti-Darwinian stance do to his career? In one sense nothing; it fitted comfortably into a dominant colonial ideology where conservative religion and science were seen to be in harmony. More intriguingly, it should be seen not through the medium of a post-Darwinian world-view, but in a specific temporal and local context. Anti-Darwinism was not an eccentric excrescence on an otherwise glittering scientific career; it was part and parcel of Frederick McCoy, a bulwark against a type of godless science that he had learned to despise through his early patrons and mentors. The science he believed in had a moral edge – it led to a wonder in the face of creation and provided the intellectual stimulus to the immense amount of work he undertook and completed in Australia. His museum philosophy was guided by this essentially providentialist science; a museum must be a teaching institution, the lessons to be learnt a combination of the factual and the moral, not a place to be filled with stuffed specimens arranged higgledy-piggledy. His adherence to Louis Agassiz's 'centres of creation' was his guide in this, even though his grand plans for the National Museum never fully materialised.

As the historians of science John Brooke and Geoffrey Cantor have said, 'In writing biography the historian or biographer seeks to identify the various strands that mould the biographical subject ... through biography we might come to appreciate the existential tensions encountered by scientists as they struggle to cope with the demands made by both science and religion' (Brooke and Cantor 1998: 247). This paper is manifestly not a biography of Frederick McCoy, but in laying out, however briefly, the factors that played a role in determining his anti-evolutionism I have sought to follow that wise advice.

Look again at the grinning ape in the glass case; it symbolically brings together the twin aspects of McCoy's scientific attitude. When McCoy invited Melbournians to view the creature he was inviting them to share his vision – of an empirical science grounded in a religious, social and moral order.

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McCoy and *Sarcophilus harrisii* Boitard, 1842 – a Diabolical Relationship

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Abstract
Frederick McCoy contributed to the knowledge of the fossil record of the Tasmanian Devil *Sarcophilus harrisii* Boitard, 1842 in Victoria by including a number of figured specimens in the *Prodromus of the Palaeontology of Victoria*. However, an article McCoy wrote under the pseudonym 'Microzoon' highlighted his anti-Darwinian thoughts and embraced a successionist viewpoint. The article, entitled 'Pre-historic Tasmanian Devils', is an interesting account of zoogeography from a successionist perspective, and is used here to contrast McCoy's anti-evolutionary viewpoint with modern Darwinian thought. A number of fossil sarcophilines discovered since McCoy's death illustrate the shortcomings of McCoy's favoured anti-Darwinian viewpoint when discussing the nature of evolution and extinction. (*The Victorian Naturalist* **118** (5), 2001, 231-233.)

Introduction

As an icon of the Tasmanian marsupial fauna, the Tasmanian Devil *Sarcophilus harrisii* Boitard, 1842, is unparalleled. Its depiction in popular culture extends from associations with sporting teams (as a symbol of aggression and determination) to children's cartoon animation, and implies the singular vision of a voracious marsupio-carnivore which cares for little else than eating and fighting. This popular misconception of the largest living dasyurid (carnivorous marsupial) is as prevalent today as it was in 1869, when Frederick McCoy published his natural history column in *The Australasian* newspaper entitled 'Pre-historic Tasmanian Devils' under the pseudonym 'Microzoon' ('Microzoon' 1869). McCoy did not identify himself as being the mysterious natural history columnist 'Microzoon'. Posthumous investigations into the numerous articles submitted under that pseudonym, however, leave little doubt as to his identity (Whitley 1969). While McCoy was not impressed with the Tasmanian Devil (nor the ecclesiastic connotations of its common name), he did seem to relish describing his contempt for *S. harrisii*. Descriptions such as 'clumsy', 'cruel', 'savage' and even '... a creature ... destitute of any redeeming quality' abound in McCoy's article, but it is McCoy's comments on the zoogeography of the species that illustrate an interesting theory. With the benefit of hindsight and a number of intriguing fossil finds since McCoy's death, a contemporary picture of the sarcophilines in time and space is slowly starting to emerge.

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McCoy's *Sarcophilus*

McCoy (1882) described the fossilised remains of a number of *S. harrisii* specimens from 'many ossiferous caves of Victoria', as well as Pleistocene sediments near Camperdown, Queenscliff, Gisborne and Baringhup (McCoy 1882). These discoveries clearly posed a dilemma for McCoy as they contradicted his belief in 'The Order and Plan of Creation' (McCoy 1869). Based on ideas from an anti-Darwinian perspective, McCoy believed not in the 'struggle for existence', but rather a 'successionist' view of creation – God's creations being punctuated by time and space. This theory was based on the idea that a certain faunal assemblage was 'created', existed in a finite time and space, then became entirely extinct, to be replaced by another 'batch' of God's creations. McCoy noted it a 'curious circumstance' that fossilised remains of an extant mammal from Tasmania could appear in mainland Australia, and found this 'quite inexplicable' (McCoy 1882). McCoy's belief in the Creator's perfect and universal plan of successive creation appeared to be contradicted by the fossil evidence McCoy himself described in the *Prodromus*.

The 'Microzoon' article only serves to highlight the shortcomings of the progres-

sionist theory – surely the smaller, outlying islands of a zoogeographic region are more at risk of faunal extinction than the larger land mass of the same region, irrespective of who or what is causing the creation and extinction. Small island communities are more susceptible to extinction by virtue of the population size, so why would the exact opposite occur? While the concept of faunal refugia was not mentioned by McCoy, in attempting to explain this conundrum in the 'Microzoon' article, McCoy had inadvertently touched on what was to become a cornerstone of Darwinian evolutionary thought, Natural Selection. The extinction of *S. harrisii* on mainland Australia is now believed to be the result of two factors, the failure of the animal to adapt to increased aridity, and its inability to compete for food with an introduced species, the Dingo *Canis lupus dingo* (Strahan 1998).

Intermediate forms and fossil Sarcophilines

McCoy, like many other anti-evolutionary thinkers, quoted the lack of 'intermediate forms' between fossils and extant fauna as an argument against Darwinian evolution. McCoy had already noted a morphological similarity between *S. harrisii* and the Spot-tailed Quoll *Dasyurus maculatus*; however he did not expand his discussion to explain the implications of this similarity. In 1911, twelve years after the death of McCoy, a specimen found in a well near Smeaton was presented to the National Museum of Victoria. It appeared to represent an intermediate fossil form linking *S. harrisii* and *D. maculatus*. The fossil, later to be named *Glaucodon ballaratensis* Stirton, 1957 was a small right jawbone of a dasyurid of Plio-Pleistocene age that was almost exactly halfway between *S. harrisii* and *D. maculatus* in both morphology and dimensions. However, as the *G. ballaratensis* holotype was missing most of its teeth (and thus the most compelling evidence of its intermediate status), the specimen remained a curiosity in dasyurid evolution for 85 years, subject to discussion of dasyurid phylogeny by many authors such as Gill (1953), Stirton (1957), Ride (1964), Marshall (1973), Archer (1976, 1982), Archer and Bartholomai (1978) and Crabb (1982).

A number of other sarcophiline fossils have also surfaced since the time of McCoy. These include the small, gracile *S. moornaensis* (Crabb 1982) of the Pliocene, and the Pleistocene's gigantic cousin of today's devil, *S. laniaris* (Ride 1964). However, it wasn't until 1996 that another specimen of the genus *Glaucodon* was discovered. This new specimen was a dentally complete lower right jaw found in Batesford Quarry near Geelong. The fossil was brought to the attention of Dr Tom Rich, Curator of Museum Victoria's Vertebrate Palaeontology Department. Dr Rich's preliminary assessment was that the fossil represented a new specimen of *G. ballaratensis* (Rich *pers. comm.* 1997). This specimen will be shown in a future work to share characteristics of both *Sarcophilus* and *Dasyurus*, thus supporting Darwinian theory rather than McCoy's.

The fossil record has many instances of specimens that appear to have shared ancestral stock. The reason there is no single 'common ancestor' in any case is partly due to the highly selective conditions required for fossilisation (and thus the bias in the fossil record). This apparent stumbling block in Darwinian evolutionary theory is often used to strengthen arguments such as McCoy's successionist perspective, however upon closer examination it shows a fundamental misunderstanding of the very nature of the Darwinian theory of evolution. It is now thought the process of evolution is based on incremental changes (mutations) in genetic structure through generations, and how these changes in genetic makeup affect the populations in their environment.

McCoy subscribed to 'Successionism', a form of Creationist theory seemingly at odds with his scientific investigations into *S. harrisii*. It is possible McCoy may have interpreted the *S. harrisii* case as an anomaly which might be dealt with at a later stage within his own scientific views. In either case, this should in no way have detracted from the concise and extensive knowledge applied to describing and illustrating *S. harrisii* and its taxonomy in the *Prodromus*. McCoy's 'Microzoon' article on *S. harrisii* is therefore an interesting example of the evolution of evolutionary thinking, and illustrates that palaeontologi-

cal evidence may never provide the definitive answer to the question on the mechanisms of extinction, but that scientific theories are shaped and re-shaped by new evidence and new interpretations.

Acknowledgements
The author is grateful to Dr Doug McCann for discussions on the life and works of Frederick McCoy.

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Editors' Notes

The manuscripts published in the two McCoy special issues vary in content and cover parts of his professional, scientific and private life. Some authors have waited a long time for their 'McCoy' papers to be published, and others prepared manuscripts at very short notice. All of the papers have been refereed and we are most appreciative of the time taken by everyone in contributing to these issues. To accommodate both the scientific and historical writing styles, there are some diversions from our usual referencing style. Many of the manuscripts also contain quotes, some of them lengthy; short quotes of a few lines are enclosed in single quotation marks, long quotes are indented in a smaller font size without quotation marks.

Readers will notice different spellings of McCoy throughout the issues – this is intentional. Frederick McCoy spelt his name several ways during his life. Neil Archbold's paper on page 234 in Part One illustrates the different spellings. Museum Victoria's name has also changed several times, so there are variations throughout the issues, depending on the time under discussion. Similarly, the date that McCoy became the first director also varies, as he was acting in this capacity for some time before the position was officially gazetted. The exact date of McCoy's birth is not known and varies with the source material.

There is some cross-referencing to other papers in the two issues. This has been done as a general guide and is not intended to be comprehensive. Cross-referenced papers have not been included in the reference lists at the end of manuscripts. Part One commences with a time line of Frederick McCoy's life and a geological time scale. We felt that these would be most useful to readers in an easy-to-find place as they will probably be referred to frequently.

The papers in Parts One and Two are not in strict chronological order. Part One (**118** (5)) is mainly about McCoy's early years in Ireland and also contains general historical papers. Part Two (**118** (6)) covers McCoy's scientific work in Australia and also some general historical material.

Merilyn Grey
Anne Morton
Alistair Evans

Revisiting the Real McCoy

N.W. Archbold[1]

It is well known to most naturalists and palaeontologists that there are numerous variations in the way that Frederick McCoy wrote his surname in his publications. In a note by Rushton (1979), McCoy is referred to as 'the versatile and prolific Irish naturalist and palaeontologist' and three forms of the surname are noted from McCoy's own publications (Fig. 1). Four additional variants of spelling, provided by citations of McCoy's works by other workers, are also noted by Rushton (Fig. 2). Rushton concluded that at least some of the variant forms are the result of typewriter and printing technique limitations (particularly issues concerning inverted apostrophes and the superior lower case c).

Rushton (1979) concludes his discussion by preferring the use of the form of McCoy with the inverted apostrophe (Fig. 1a) but considered that, as an alternate method, the 'rare form McCoy' could also be used. It is odd that Rushton shows little if any awareness of McCoy's work in Victoria and his long career of publishing in the colony. Indeed, McCoy could well be referred to as 'the versatile and prolific Victorian naturalist and palaeontologist'. Considerable variation occurs in the surname spelling of McCoy during the late 1850s and 1860s. McCoy's name is given in two styles, those of Fig. 1a and 1c herein, in the William Fairfax, *Handbook to Australasia* of 1859. The *Catalogue of the 1861 Victorian Exhibition* (English Edition) gives it as McCoy while the German edition gives two forms; McCoy and M'Coy). Both the *Annals and Magazine of Natural History* (1862, 1868) and the *Quarterly Journal of the Geological Society of London* (1862) use the inverted apostrophe as does the *Melbourne Intercolonial Exhibition, 1866-67, Official Record* (1867). During the same period the *Transactions and Proceedings of the Royal Society of Victoria* uses both McCoy (1860) and the inverted apostrophe version (1865).

During the 1870s, and subsequently, McCoy consistently used the lower case c as an inferior letter in his palaeontological reports for the *Progress Reports* and later *Annual Reports of the Geological Survey of Victoria.* The same form was used throughout his text for the progressively issued major works, the *Prodromus of the Palaeontology of Victoria* and the *Prodromus of the Zoology of Victoria.* These latter works ensure that 'McCoy' is the real McCoy to naturalists in Victoria (and Australia) and hence rather than being 'the rare form' of his name as stated by Rushton (1979), it is, instead, a common form.

But even in the two major *Prodromus* works there is an interesting footnote to the story. The lithographic plates for these two major works were prepared by a number of artists. Each plate was acknowledged at its base as having been prepared under the direction of McCoy, the spelling of which varies! The early plates (prepared by Ludwig Becker in the late 1850s) were directed by M'Coy, with a normal apostrophe, all subsequent plates were directed by McCoy but using the lower case c as a superior letter!

M'COY	A
M^{c}COY	B
McCOY	C

Fig. 1. Three forms of McCoy's name as published. a. 1844, b. 1855, c. 1875.

M'Coy	A
MacCoy	B
Mac Coy	C
Mac'Coy	D

Fig. 2. Four additional forms of McCoy's name as quoted from secondary sources by Rushton (1979).

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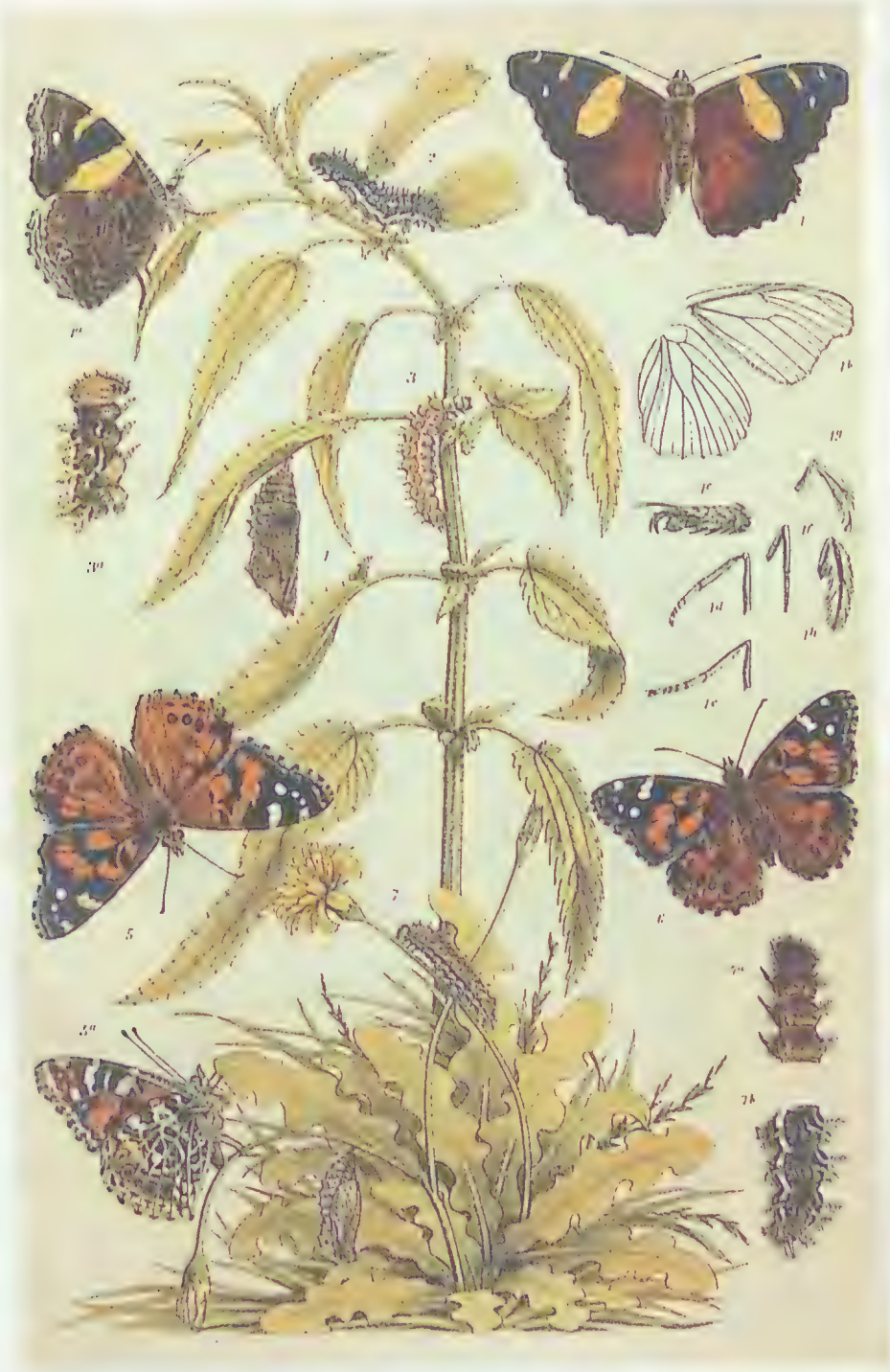

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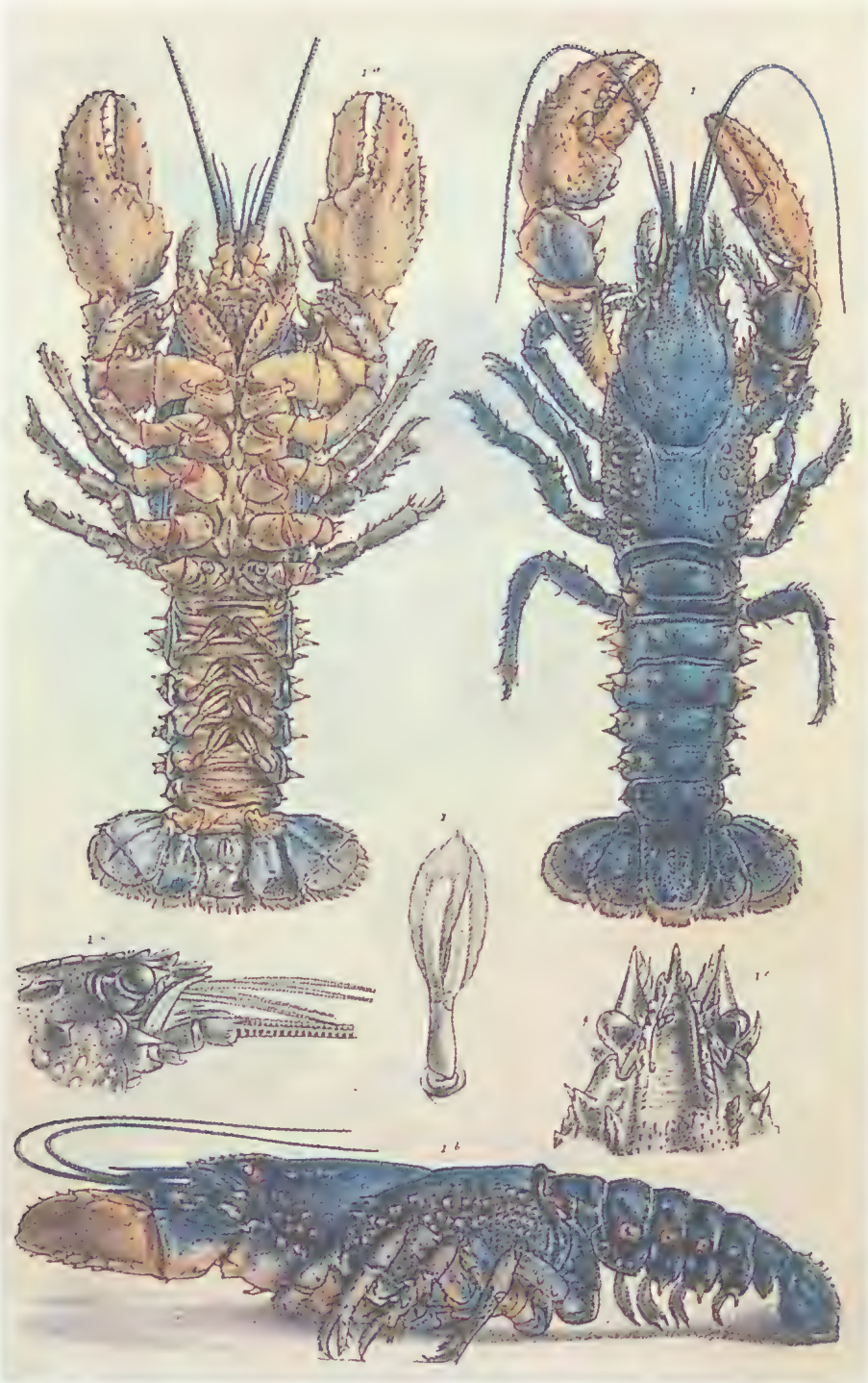

Plate 2

Plate 3

The Victorian Naturalist

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McCoy's *Prodromus of the Zoology of Victoria* – an Unfinished Task, *by A.L. Yen, S.Boyd, A.J. Coventry, J. Dixon, M. Gomon, M. O'Loughlin, G. Poore and K. Walker* 242

The Bryozoa of McCoy's *Prodromus*, *by Philip Bock* 256

McCoy's Contribution to Graptolithology, *by Noel Schleiger* 266

McCoy's Mammals, *by John Seebeck and Robert M. Warneke* 277

Comments on the Ostracod Genus *Bairdia* M'Coy, 1844, *by Mark Thomas Warne* 283

A 'Bite' from the Past, *by Leigh Ahern* 285

Frederick McCoy – the Challenge of Interpretation of Thylacoleonid Fossil Material, *by Bernard Mace* 287

M'Coy and the Australian Ichthyosaur *Ichthyosaurus australis* (M'Coy, 1867), *by A.J. Hell* 294

Animal Acclimatisation: McCoy and the Menagerie That Became Melbourne's Zoo, *by Linden Gillbank* 297

The Fate of the Cranbourne Meteorites, *by Sara Maroske* 305

Frederick McCoy and the Naturalist Tradition, *by Doug McCann* 309

Frederick McCoy and the FNCV, *by Sheila Houghton* 314

Frederick McCoy's Mount Macedon Property, *by Doug McCann* 319

The History of the McCoy Society, *by David H. Ashton* 321

Captions to coloured plates 328

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Cover: Sir Frederick McCoy, 1891, to commemorate the award of KCMG. Reproduced courtesy of Museum Victoria.

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McCoy's *Prodromus of the Zoology of Victoria* – an Unfinished Task

A.L. Yen[1,2], S. Boyd, A.J. Coventry, J. Dixon,
M. Gomon[1], M. O'Loughlin, G. Poore[1] and K. Walker[1]

Abstract
Frederick McCoy published the *Prodromus of the Zoology of Victoria* between 1878 and 1890. It included text and illustrations on 447 species of invertebrates and vertebrates. The aim was to make people more aware of Victoria's natural history. Although it was not continued after 1890, the *Prodromus* contains important biological and distributional information about many species, some of which are now threatened with extinction. (*The Victorian Naturalist* **118** (6), 2001, 242-255.)

Introduction

One of the lesser known contributions to our knowledge of the zoology of Victoria is Frederick McCoy's *Prodromus of the Zoology of Victoria*. Between 1878 and 1890, McCoy published this Zoology *Prodromus* as 20 parts in two volumes (Pescott 1954). Each part comprised 10 plates, so a total of 200 plates was published. There was often more than one species on each plate, so the total number of species recorded in the *Prodromus* was 447. McCoy also prepared a *Prodromus of the Palaeontology of Victoria*, and a more detailed account of the history of the production of both these texts is outlined by Darragh (2001).

What is a *Prodromus*? The Oxford Dictionary defines a 'prodromus' as a preliminary book or treatise. The Government of the day deemed it necessary to acquire knowledge on the geology, botany and zoology of the Colony of Victoria 'to form collections illustrative of each for the public use, and to make the necessary preparations for such systematic publications on the subject as might be useful and interesting to the general public, and contribute to the advancement of science' (McCoy 1878, in Preface to Volume 1).

McCoy stated that the publication required a large number of illustrations made of living or fresh examples of many species of reptiles, fish and the lower animals because (1) they were not as well known as the flora; (2) they lose their natural appearance shortly after death; and (3) not all true characters had been recorded, as many were described from preserved specimens. The illustrations were reproduced lithographically, and several different artists were involved (Darragh 2001). In many cases, the illustrations were the first time that the species was illustrated, sometimes for the first time in colour.

McCoy saw the *Prodromus* as a preliminary issue in the form of 'Decades' (10 plates). There was no systematic order to the sequence of publication, nor did he wait until particular groups were thoroughly known. It was aimed to encourage people to observe natural history objects and to send new material to the National Museum of Victoria for description. McCoy saw the *Prodromus* as a step towards the publication of the final systematic volume for each class when they approached completion. The publication years for each part (Decade) were 1878 (Decades 1 and 2); 1879 (3 and 4); 1880 (5); 1881 (6); 1882 (7); 1883 (8); 1884 (9); 1885 (10 and 11); 1886 (12 and 13); 1887 (14 and 15); 1888 (16 and 17); 1889 (18 and 19); and 1890 (20).

Many of the species that McCoy included in the *Prodromus* have been renamed and some species have been split into two or more species in subsequent taxonomic revisions. This paper will provide the currently accepted scientific and common names of the taxa in the *Prodromus*, as well as some notes where relevant. Information on the changes has been provided by Sue Boyd (molluscs and echinoderms); John Coventry (snakes, lizards, frogs, tortoises and turtles); Joan Dixon (mammals); Martin Gomon (fish); Mark

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O'Loughlin (echinoderms); Gary Poore (crustaceans); Ken Walker (insects); and Alan Yen (insects, earthworm).

The fauna

Not all species in the *Prodromus* were new, although a number of new species described by McCoy were included. Of the 447 species outlined in the *Prodromus*, 16 were species originally described by McCoy. However, only 14 of these species had their original descriptions in the *Prodromus*. The two species described by McCoy prior to the publication of the *Prodromus* were Leadbeater's Possum, originally described by McCoy in 1867, and the Painted Lady Butterfly (described in 1868). The following were McCoy species: the Giant Gippsland Earthworm, Gould's Squid, two species of stick insects, the Painted Lady Butterfly, four species of fish (the Two-pronged Toadfish, the Melbourne Pelamyde, Macleay's Wrasse and the Blotch-tailed Trachinops), five species of snakes (Little Whip Snake, Common Brown Snake, Small-scaled Brown-Snake, Shield-fronted Brown Snake and the Two-hooded Furina-Snake), one species of lizard (Victorian Rhodona), one subspecies of lizard (Gippsland Water Dragon) and one mammal species (Leadbeater's Possum).

Table 1 lists the species outlined by McCoy. They have been re-arranged according to their appropriate groups rather than following the order used by McCoy. For each species, the *Prodromus* issue in which it is described, the scientific and common names given by McCoy, and the currently accepted scientific and common names are given, along with some notes of interest. Some of the species do not have a specific common name.

Polyzoa

These animals belong to the Phylum Polyzoa and are also known as Bryozoa. A total of 298 taxa was included and each was described by a polyzoan expert, Dr Paul MacGillivray, from Bendigo.

Mollusca

There were four species of molluscs, all of which were cephalopods. These were two species of cuttlefish, an octopus (Paper Nautilus) and Gould's Squid (now known as the Arrow Squid). The latter was described by McCoy.

Echinoderms

McCoy included four species of echinoderms, three species of sea stars and a species of sea urchin.

Annelida

Only one species of earthworm was included, and this was McCoy's original description of the Giant Gippsland Earthworm *Megascolides australis*.

Crustacea

A total of seven Crustacea taxa was included. He dealt with very few of the species of Crustacea now known to exist in Victoria. In the family dealt with in most detail, Parastacidae or freshwater crayfish, the number of species now recognised is far greater. With few exceptions his family, genus and species names have been revised.

Insects

McCoy dealt with 26 species of insects, including three species that he described, although one of these, the Australian Painted Lady Butterfly, had been described prior to the publication of the *Prodromus*. The insects that McCoy included in the *Prodromus* were generally large-bodied and often brightly coloured species that would generally have attracted people's attention. McCoy included the immature life history stages of moths and butterflies, which would have aided identification considerably.

Fish

The 61 species of fishes treated by McCoy make it the second largest 'group' to feature in the *Prodromus*. It is estimated that well over 600 species occur in Victorian waters. The coverage reveals a predominance of species that might have been expected to turn up in early fish markets, or species, like the Basking Shark, Briar Shark and Tasseled Anglerfish, that were perhaps brought to McCoy's attention because of their peculiar nature. Since the publication of the *Prodromus*, there have been major changes in fish taxonomy. As a result, only one of the five new species, *Trachinops caudimaculatus*, retains that

name, and a large proportion of the species are now junior synonyms. Less than a third of the scientific names provided by McCoy are recognised today, with a number of the 'correct' names differing in spelling from that currently in use. Eight species have since been referred to other genera.

Though most species presented occur in Port Phillip Bay, or are oceanic species that are occasionally reported from Bass Strait coasts, one, the Sand Whiting *Sillago ciliata*, lives along the coasts of Queensland and New South Wales, and is unlikely to be found in Victorian waters. The inclusion of the Grey Nurse Shark is interesting, as is the commentary about its abundance in Port Phillip Bay where it was considered a nuisance to commercial fishers. At present, the species is all but absent from Victorian waters, and was recently considered by the Victorian Department of Natural Resources and Environment as warranting placement in a conservation category that would afford it protection.

Frogs, Snakes, Lizards, Tortoises and Turtles

McCoy included three species of frogs, 14 species of snakes, 21 species of lizards, two species of tortoises and a species of turtle. Six of these species, including four species of snakes, involved original descriptions by McCoy.

Mammals

Only five species of mammals were included, of which four were marine species. The one terrestrial species, Leadbeater's Possum, is significant because it is one of Victoria's faunal emblems. It was thought to be extinct for almost 50 years, but was rediscovered by Museum staff in 1961. Although few in number, the mammals figured and described in the *Prodromus* were treated in much detail, though McCoy's understanding of the taxonomy of the seals was confused. As an example, although he confused the taxonomy of the Australian Sea Bear, his excellent observations made on animals living on the Seal Rocks off the Nobbies on the coast of Victoria remained a primary source of information on this species until Wood Jones (1925).

Significance of the *Prodromus of the Zoology of Victoria*

McCoy, besides providing a detailed description of each species, attempted to illustrate the species in true colours. To this end, he provided illustrations of 13 species for the first time and nine species in true colours for the first time.

There was no apparent rhyme or reason as to how the species were selected for the *Prodromus*. Over half the species included were bryozoans, not a group of great public concern or interest at the time. However, McCoy used the expertise of Dr P.H. MacGillivray who was a specialist on bryozoans. Of the better known groups, no birds and only one species of non-marine mammal (Leadbeater's Possum) were included. It is likely that McCoy did not include any birds because the fauna was considered well known and there were books on the birds available, such as Gould's handbook (1865). The mammals were covered by the publications of John Gould (Gould 1845-1863). Surprisingly, given McCoy's interest in venomous snakes, there were no spiders or scorpions included. The snakes of Australia had already been well covered by Krefft (1869), but McCoy described four more species.

McCoy also provided information on the natural history of some species, both scientific and anecdotal. For example, the documented effects of the bite of a Copper-head Snake on a station-master at Elsternwick, who was considered to be at the point of death until given an injection of strong liquor of ammonia! Other information verges on the bizarre, such as McCoy's comments on a specimen of the White Pointer Shark in the Museum collection: 'Our two specimens were caught, one in July, 1873, and one in April 1877, in Hobson's Bay, near Brighton. The larger had been observed for several days swimming around the ladies' baths, looking in through the picket fence in such a disagreeable manner that the station master had a strong hook and iron chain made so as to keep the rope out of reach of his teeth, and this, being baited with a large piece of pork, made to look as much like a

piece of a lady as possible, was swallowed greedily; and then, with the aid of a crowd of helpers, the monster was got on shore.'

However, there is considerable information on the distribution of many of the species during the early settlement of Melbourne that is of importance to conservation today. McCoy recorded a large number of species found in areas close to Melbourne, which may now be extinct in Victoria (such as the Earless Dragon *Tympanocryptis lineata pinguicolla,* now a full species, *Tympanocryptis pinguicolla*, which was common around Essendon and Sunbury), or locally extinct, or very much reduced in numbers (such as the Striped Legless Lizard *Delma impar*). It is interesting to note that 16 species of fish were collected from Hobson's Bay.

Another interesting side issue is whether all the species that McCoy had in his *Prodromus* are actually Victorian. One of the species that he described was the Inland Taipan or Fierce Snake. Although McCoy listed the specimens as originating from the junction of the Murray and Darling Rivers, it is likely that these specimens were collected in New South Wales during the Blandowski Expedition of 1857-8; the location is Blandowski's camp site. McCoy also stated that the Death Adder was very common in the warmer parts of northern Victoria near the Murray River; in fact, the only record of a Death Adder was a specimen from Lake Boga that had been illustrated by Krefft.

Despite its narrow scope of coverage in light of what is known about Victoria's fauna today, the *Prodromus* was a bold attempt to document the fauna. Its progression was no doubt hindered by the need to prepare colour lithographs of the species, but McCoy's initial aim to provide true colour illustrations in the days before colour photographs is laudable. The *Prodromus* was not fully recognised during McCoy's lifetime. There were efforts made in 1902, after McCoy's death, to get the Government to continue the series to cover more of the natural history of Victoria, but to no avail. It was found that McCoy had prepared more than the 200 plates in the two decades published, but he had not prepared any text to accompany these plates. The knowledge gathered by McCoy on the unpublished plates was lost upon McCoy's death (Pescott 1954). For example, McCoy prepared an illustration of a specimen of an undescribed species of legless lizard. This figured specimen is still in the Museum collection, with McCoy's proposed name, '*Pygopus porcatus*'. McCoy never wrote a formal description and this species was described by Fischer in 1882 as *Pygopus nigriceps*.

The *Prodromus* illustrates McCoy's all-round ability as a natural scientist. He was a palaeontologist, but described species from a diverse range of animal groups: snakes, lizards, squid, mammals, fish and insects. McCoy did not revise any particular groups, unlike his successor, Baldwin Spencer, who published several papers on Victorian earthworms. However, McCoy recognized that there was still a wealth of material waiting to be described, and the publication of the *Prodromus* was an important initial step in bringing this to public attention.

Acknowledgements

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Editors' note: Some examples of the beautiful coloured lithographs from McCoy's *Prodromus of the Zoology of Victoria* are reproduced in the colour plates at the beginning and end of this issue.

Table 1. List of taxa covered by McCoy in the Zoology *Prodomus*.

Prodromus Decade	Faunal group	Scientific name listed by McCoy	Common name given by McCoy	Current scientific name	Current common name	Notes
I (Plate 7)	Earthworm	*Megascolides australis* (McCoy)	The Giant Earth-Worm	*Megascolides australis* (McCoy)	Giant Gippsland Earthworm	Original description of a giant earthworm from South Gippsland. McCoy made the common error of assuming that the conical burrows of land crayfish were the surface casts of this earthworm; *M.australis* leaves its casts below ground. It has declined in its distributional range and is a protected species at the State level and was the first invertebrate to be listed as Vulnerable on the Commonwealth list.
VII (Plate 61, 62)	Mollusc	*Argonauta oryzata* (Meusch.)	Paper Nautilus	*Argonauta nodosa* Solander	Paper Nautilius	The earlier name McCoy used was placed into synonymy by Robson (1931).
VIII (Plate 76, 77)	Mollusc	*Sepioteuthis Australis* (Quoy and Gaim)	Australian Tooth-cupped Cuttlefish	*Sepioteuthis australis*	Southern Calamary	
X (Plate 100)	Echinoderm	*Goniocidaris tubaria* (Lam)		*Goniocidaris tubaria*	Slate Pencil Urchin	This species continues to be found commonly in Port Phillip and Western Port Bays as noted by McCoy.
XVII (Plate 169, 170)	Mollusc	*Ommastrephes Gouldi* (McCoy)	Gould's Squid	*Notodarus gouldi*	Arrow Squid	
XIX (Plate 188, 189, 190)	Mollusc	*Sepia apama* Gray	Melbourne Sepia or Cuttle-fish	*Sepia apama*	Australian Giant Cuttlefish	
XX (Plate 200)	Echinoderm	*Asterina calcar* Lam.	Eight-rayed Cushion Starfish	*Patiriella calcar*	Common Sea Star	A very common shallow water sea star, as indicated by McCoy.
XX (Plate 200)	Echinoderm	*Asterina Gunni* Gray	Gunn's Cushion Starfish	*Patiriella gunni*	Small Sea Star	Recent molecular studies indicate that there may be more than one species in this group.
XX (Plate 200)	Echinoderm	*Pentagonaster (Tosia) aurata* (Gray)	Twelve-plated Shield-Star	*Tosia magnifica*	Greater Biscuit Star	This species is found in Port Phillip Bay but rarely seen in the shallows. McCoy accurately distinguishes this species from the more common *Tosia australis* Gray, 1840.
II (Plate 15)	Crustacea	*Astacopsis serratus* Shaw	Murray Lobster	*Euastacus armatus*	Murray Spiny Crayfish	McCoy used Astacidae, a family now confined to the northern hemisphere. The specific name *serratus* is no longer valid.
III (Plate 29)	Crustacea	*Astacopsis bicarinatus* Gray	Yabber Crayfish	*Cherax destructor*	Yabby	The Yabby is a largely Victorian species. *Cherax bicarinatus* is confined to the Northern Territory.
XV (Plate 149, 150)	Crustacea	*Palinurus Lalandi* Lam.	Southern Spiny Lobster, Melbourne Craw-fish	*Jasus edwardsii novaehollandiae*	Southern Rock Lobster	The species is at best a subspecies, genetically and morphologically only slightly distinct from the New Zealand species, *J. edwardsii*. In spite of McCoy's extensive commentary *lalandi* is referable only to the South African species.
XVII (Plate 159)	Crustacea	*Palinurus Hugeli* Heller	Sydney Craw-fish or Spiny Lobster	*Jasus verreauxi*	Eastern Rock Lobster	This species is the basis of a fishery in NSW but is rare in Victoria. The species *huegeli* is generally synonymised with *verreauxi* but is a potential name for the very similar New Zealand species.
XVII (Plate 160)	Crustacea	*Astacopsis serratus* Shaw	Yarra Spiny Cray-fish	*Euastacus yarraensis*	Yarra Spiny Crayfish	Now treated as a species rather than subspecies.

Prodromus Decade	Faunal group	McCoy scientific	McCoy common	Current scientific	Current common	Notes
XVIII (Plate 179, 180)	Crustacea	*Pseudocarcinus gigas* Lam.	Great Red King-Crab	*Pseudocarcinus gigas*	Tasmanian Giant Crab	This species is the heaviest crab in the world but is not a king-crab.
XX (Plate 199)	Crustacea	*Ibacus Peronii* Leach	Peron's Ibacus Crab	*Ibacus peronii*	Balmain Bug	
I (Plate 8)	Insect	*Agarista Lewini* Boisd.	Lewin's Day-moth	*Phalaenoides tristifica* (Hubner)	?	
I (Plate 8)	Insect	*Agarista Casuarinae* Scott	Loranthus Day-moth	*Comocrus behri* (Angas)	?	
I (Plate 8)	Insect	*Agarista Glycine* Lewin	Vine Day-moth	*Phalaenoides glycinae* Lew.	Vine Moth	A native species that adapted to grape vines. McCoy mentions that the Acclimatisation Society introduced the Indian Mynah to control grape pests, but the birds preferred the grapes to the insects.
I (Plate 9)	Insect	*Pieris (Thyca) Harpalyce* Don.		*Delias harpalyce* (Donovan)	Imperial White Butterfly	
I (Plate 10)	Insect	*Pieris (Thyca) Aganippe* Don.		*Delias aganippe* (Donovan)	Wood White Butterfly	
III (Plate 30)	Insect	*Zeuzera Eucalypti* Boisd. Herr.-Schaet.	Large Wattle Goat-Moth	*Xyleutes eucalypti* (Herrichs-Schäffer)	Wattle Goat Moth	
IV (Plate 40)	Insect	*Metura elongata* Saunders	Saunders' Case-Moth	*Oiketicus elongatus* Saunders	Saunders' Case-Moth	
IV (Plate 40)	Insect	*Entometa ignobilis* Walk.	Lictor Case-Moth	*Clana ignobilis* (Walker)	Faggot Case Moth	
V (Plate 50)	Insect	*Cicada moerens* (Germ.)	Great Black, or Manna cicada	*Psaltoda moerens* (Germar)	Redeye	A species that can be very common one year and absent the next. Kershaw (1897) reported thousands inhabiting a few trees near Dandenong in 1896.
V (Plate 50)	Insect	*Cyclochila Australasiae* (Donov.)	Great Green cicada	*Cyclochila australasiae* (Donovan)	Greengrocer	A species that has adapted to cities because it can utilise introduced trees such as liquidamber, weeping willow, poplar and oak.
VII (Plate 69, 70)	Insect	*Tropidoderus iodomus* (McCoy)	Violet-shouldered Phasma	*Tropidoderus iodomus* (McCoy)	?	Original description by McCoy.
VII (Plate 69, 70)	Insect	*Tropidoderus rhodomus* (McCoy)	Red-shouldered Phasma	*Tropidoderus rhodomus* (McCoy)	?	Original description by McCoy.
VIII (Plate 79)	Insect	*Acrophylla violescens* (Leach)	Violet-winged Phasma	*Didymuria violescens*	Violet Stick-insect	A species that defoliated Mountain Ash forests in the Central Highlands during the 1960-1970s.
VIII (Plate 80)	Insect	*Podacanthus typhon* (Gray)	Large Pink-winged Phasma	*Podacanthus typhon* (Gray)	?	McCoy noted that this species was found around Richmond Hill and Melbourne.
XI (Plate 109)	Insect	*Locusta vigentissima* (Serv)	The Great Green Gum-tree Grasshopper	*Terpandrus* sp.	?	The first illustration of this species.

Prodromus Decade	Faunal group	McCoy scientific	McCoy common	Current scientific	Current common	Notes
XI (Plate 110)	Insect	*Edipoda musica* (Fab)	Australian Yellow-winged Locust	*Gastrimargus musicus* (Fabricus) (Acrididae)	Yellow-winged Locust	
XII (Plate 119)	Insect	*Phaneroptera valida* (Walk)	Smaller Green Gum-tree Grasshopper	*Caedicia valida*	?	
XII (Plate 120)	Insect	*Phaneroptera [Ephippitytha] trigintiduoguttata* (Serv.)	The Thirty-two Spotted Grasshopper	*Ephippitytha trigintiduoguttata* (Serville) (Tettigoniidae)	Mottled Katydid	
XIII (Plate 129)	Insect	*Acripeza reticulata* (Guérin).	The Netted Acripeza	*Acripeza reticulata* Guérin-Méneville (Tettigoniidae)	Mountain Katydid	The males of this species have full wings while the females have very reduced wings and are unable to fly.
XIII (Plate 130)	Insect	*Mantis latistylus* (Serv.)	Broad-styled Mantis	*Archimantis latistylus* (Serville)	Large Brown Mantid	
XIV (Plate 139)	Insect	*Opsomala sordida* (Aud.Serv.)	Dusky Flat-horned Locust	*Coryphistes ruricola* (Burmeister)	?	The first illustration of this species.
XIV (Plate 139)	Insect	*Mesops pedestris* (Erichson)	Pedestrian Mid-Eyed Locust	*Psednura pedestris* Erichson	?	
XIV (Plate 140)	Insect	*Tropinotus Australis* (Leach)	The Cinnamon Keel-backed Locust	*Goniaea australiasiae* (Leach)	?	
XX (Plate 197)	Insect	*Chelepteryx Collesi* (Gray)		*Chelepteryx collesi* (Gray)	White Stemmed Gum Moth	
XX (Plate 198)	Insect	*Pyrameis Kershawi* McCoy	Blue-spotted Painted-Lady Butterfly	*Vanessa kershawi* (McCoy)	Australian Painted Lady	Described by McCoy in 1868 and named after the Museum taxidermist William Kershaw who collected insects for the Museum collection.
XX (Plate 198)	Insect	*Pyrameis Itea* Fabr.	Australian Admiral Butterfly	*Vanessa itea* Fabricus	Australian Admiral	
I (Plate 4)	Fish	*Chrysophrys Australis* Günth.	Australian Bream	*Acanthopagrus butcheri* (Munro 1959)	Black Bream	Previously confused with the Yellowfin Bream *Acanthopagrus australis* of southern Queensland and New South Wales, the Black Bream was not formally recognised as distinct until nearly 1960. Both species occur in the region of Lakes Entrance.
I (Plate 5)	Fish	*Lepidotrigla Vanessa* Rich.	Spiny-sided Butterfly-Gurnard	*Lepidotrigla vanessa*	Butterfly Gurnard	The Butterfly Gurnard gets both its common and scientific name from its colorful wing-like pectoral fins which are used for display rather than flying.
I (Plate 6)	Fish	*Trigla Kumu* Lesson & Garn.	Kumu Gurnard	*Chelidonichthys kumu*	Red Gurnard	This is probably the most widely distributed of all gurnards, having been reported from South Africa to Hawaii.
II (Plate 14)	Fish	*Lates colonorum* Günth.	Gippsland Perch	*Macquaria colonurum*	Estuary Perch	Superficially resembling the barramundi of the tropics, this species was initially described in the same genus but is closely related to the Murray Cod and its freshwater relatives.

Prodromus Decade	Faunal group	McCoy scientific	McCoy common	Current scientific	Current common	Notes
II (Plate 16, 17)	Fish	*Arripis truttaceus* Cuv.	Salmon Arripis	*Arripis truttacea*	Western Australian Salmon	Migratory in habit, both the Eastern Australian Salmon *Arripis trutta* and the Western Australian Salmon occur in Victorian waters, but it is likely that McCoy described the western species, which at times is common in Port Phillip Bay.
II (Plate 18)	Fish	*Trachurus trachurus* Lin.	Horse Mackerel	*Trachurus declivis* (Jenyns, 1841)	Cowanyoung	Despite having been recognised as distinct by the mid-1800s, this species was given a name which applies to a northeastern Atlantic species by McCoy, a practice at the time that was not uncommon for writers whose interests were not solely fishes.
II (Plate 19)	Fish	*Lotella callarias* Günth.	Small-scaled Rock Cod	*Lotella rhacinus* (Bloch & Schneider 1801)	Largetooth Beardie	The name *Lotella callarias* was widely retained in Australia for this species until the early 1980s when it was finally accepted that the New Zealand name was a synonym and it had precedence.
II (Plate 20)	Fish	*Pseudophysis barbatus* Günth.	Australian Rock Cod	*Pseudophysis barbatus*	Bearded Rock Cod	Like the Largetooth Beardie, this species is a common inhabitant of rock reefs of Port Phillip Bay that appeared regularly in early fish markets.
III (Plate 27)	Fish	*Genypterus Australis* Cast.	Australian Rockling	*Genypterus tigerinus* Klunzinger 1872	Rock Ling	Another common inhabitant of inshore reefs, the Rock Ling has been replaced in fish markets by the closely related Pink Ling, which is taken in greater numbers by deep-water trawlers.
III (Plate 27)	Fish	*Gadopsis gracilis* McCoy	Yarra Blackfish	*Gadopsis marmoratus* (Richardson, 18??)	River Blackfish	Once thought to be a single widespread species, this Australian endemic is proving to be a complex of species, each isolated in localised drainages.
III (Plate 28)	Fish	*Scomber pneumatophorus* De la Roche	Southern Mackerel	*Scomber australasicus* Cuvier, in Cuvier and Valenciennes 1831	Blue Mackerel	The three species in the genus *Scomber* are by far the most commercially important of the mackerels and tunas throughout the world. The local Blue Mackerel is fished both for human consumption and pet food.
IV (Plate 33)	Fish	*Sebastes percoides* Solander	Banded Red Gurnet-Perch	*Helicolenus percoides* (Richardson 1842)	Ocean Perch	There appear to be two species going under this name, a darkly patterned shallow water form and a paler deep water form, but further work is required to properly separate the two.
IV (Plate 34)	Fish	*Rhina squatina* Lin.	Angel-fish	*Squatina australis* Regan 1906	Angelshark	Angelsharks are midway between sharks and rays in appearance, retaining the lateral gill slits of sharks but developing the close association of the pectoral fins and flattened head of rays.
V (Plate 43)	Fish	*Crossorhinus barbatus* (Lin.)	Carpet Shark	*Orectolobus ornatus* (DeVis 1883)	Banded Wobbegong	The highly camouflaged wobbegongs are usually inactive during daylight hours, preferring to forage about their algal covered reefs at night.
V (Plate 43)	Fish	*Notidanus [Heptanchus] Indicus* (Cuv)	Seven-gilled Shark	*Notorynchus cepedianus* (Péron 1807)	Broadnose Sevengill Shark	This shark has a primitive feature of seven gill slits, instead of the five of 'modern' sharks, and teeth that match those of fossil relatives living 40-50 million years ago.
V (Plate 44)	Fish	*Thersites atun* (Cuv)	Barracouta	*Thyrsites atun*	Barracouta	Once an extremely important food fish in southern waters, Barracouta populations have declined to the point where it is rarely seen in markets.
V (Plate 44)	Fish	*Thynnus Thynnus* (Lin.)	The Tunny	*Thunnus maccoyii* Castelnau 1872	Southern Bluefin Tuna	Described by McCoy well before the publication of the *Prodromus*, he evidently did not consider it to be a species distinct from Bluefin Tuna of the Northern Hemisphere.

Prodromus Decade	Faunal group	McCoy scientific	McCoy common	Current scientific	Current common	Notes
VI (Plate 54, 55)	Fish	*Aulopus purpurisatus* (Rich.)	Australian Aulopus	*Aulopus purpurissatus*	Sergeant Baker	A species associated with rocky reefs of the open coast, the Sergeant Baker has long been considered a desirable food fish, but is not often seen in markets.
VI (Plate 56)	Fish	*Zygaena malleus* (Shaw)	Hammer-headed Shark	*Sphyrna zygaena* (Linnaeus 1758)	Smooth Hammerhead	While other species of hammerhead shark occur in tropical oceans, the Smooth Hammerhead is distributed in temperate regions throughout the world.
VI (Plate 56)	Fish	*Pristiophorus nudipinnis* (Günth)	Common Australian Saw-Fish	*Pristiophorus nudipinnis*	Southern Sawshark	The saw-like rostrum of sawsharks has developed quite independently from that of sawfish, although it is likely to be used in both for wounding prey.
VII (Plate 63)	Fish	*Myliobatus australis* (Macleay)	Blue-spotted Eagle-Ray	*Myliobatus australis*	Southern Eagle Ray	These rays are powerful swimmers that cruise sandy coastal shorelines in search of shellfish, on which they feed.
VII (Plate 64)	Fish	*Odontaspis taurus* (Rafin.)	Long-Toothed Bull-Shark, Shovel-nosed Shark	*Carcharias taurus*	Grey Nurse Shark	Now all but absent from Victorian waters, the Grey Nurse Shark was said by McCoy to be so common in Port Phillip Bay as to be a nuisance.
VII (Plate 64)	Fish	*Galeus australis* (Macleay)	Australian Tope Shark	*Galeorhinus galeus* (Linnaeus 1758)	School Shark	A temperate species of most oceans, the School Shark is a major component of the Victorian flake fishery and, as a result, is declining in numbers.
VII (Plate 65)	Fish	*Phyllopteryx foliatus* (Shaw)	Leafy Sea-Dragon	*Phyllopteryx taeniolatus* (Lacepède 1804)	Common or Weedy Seadragon	One of the unique fishes of southern Australia, this species is more widely distributed than the true Leafy Seadragon, which is confined to Australia's central southern and southwestern coasts.
VII (Plate 65)	Fish	*Hippocampus breviceps* (Peters)	Short-Headed Sea-Horse	*Hippocampus breviceps*	Shortsnout Seahorse	This is the smaller of two seahorses living in bays and coastal waters of Australia's southern coasts.
VIII (Plate 73)	Fish	*Girella simplex* (Rich.)	Ludrick	*Girella tricuspidata* (Quoy and Gaimard 1824)	Luderick	This species is more commonly known as blackfish along the New South Wales coast, where it is an extremely popular angling fish.
VIII (Plate 74)	Fish	*Carcharodon Rondeletii* (Müll. and Hen.)	White Shark	*Carcharodon carcharias* (Linnaeus 1758)	White Pointer	Referred to as the Great White Shark elsewhere in the world, this is the feared 'man eating shark' of maritime lore.
VIII (Plate 75)	Fish	*Acanthias vulgaris* (Linn.)	Picked Dog-Fish	*Squalus acanthias* Linnaeus 1758	White-spotted Spurdog	This species is fished heavily in the Atlantic for the fish and chip market, but is largely ignored in Australia because of the small size of the population. It has virtually disappeared from Victorian waters.
IX (Plate 84)	Fish	*Ctenolates ambiguus* (Rich)	Murray Golden Perch	*Macquaria ambigua*	Golden Perch	The Golden Perch is a popular food fish of the Murray-Darling River system but does not occur naturally south of the Great Divide.
IX (Plate 85, 86)	Fish	*Oligorus Macquariensis* (Cuv and Val.)	Murray Cod-Perch	*Maccullochella peelii* (Mitchell 1838)	Murray Cod	Also confined to the Murray-Darling River system, the Murray Cod is Australia's largest bony fish, reaching 1.8m and 110 kg.
IX (Plate 87)	Fish	*Mustelus Antarcticus* (Günth.)	Australian Smooth-Hound	*Mustelus antarcticus*	Gummy Shark	The Gummy Shark receives its common name from the pavement-like teeth in its jaws, in contrast to the pungent teeth of most sharks.
IX (Plate 88)	Fish	*Alopecias vulpes* (Linn.)	The thresher, or Long-tailed Shark	*Alopias vulpinus* (Bonnaterre 1788)	Thresher Shark	Thresher Sharks are distinctive sharks of the world's open oceans, having a greatly elongated upper lobe of the tail fin. This is the most widely distributed of the three species and reaches well into temperate regions of both hemispheres.

Prodromus Decade	Faunal group	McCoy scientific	McCoy common	Current scientific	Current common	Notes
XI (Plate 104)	Fish	*Cetorhinus maximus* (Linn.)	Basking Shark	*Cetorhinus maximus*	Basking Shark	The Basking Shark attains a length of 10 m and is the cold-water equivalent of the Whale Shark, both feeding on relatively tiny plankton.
XII (Plate 112)	Fish	*Callorhynchus antarcticus* (Lacép)	Southern Chimaera	*Callorhynchus milii* Bory de St. Vincent 1823	Elephantfish	This odd-looking primitive fish, like sharks and rays, retains a cartilaginous skeleton and has modified pelvic fins for internal fertilisation. Its strange elephant-like snout has a sensory function.
XII (Plate 113)	Fish	*Heterodontus Phillipi* (Lacép)	Port Jackson Shark, or Bull-dog Shark	*Heterodontus portusjacksoni* (Meyer 1793)	Port Jackson Shark	The primitive Port Jackson Shark has pointed grasping teeth at the front of the jaws, and crushing molars at the rear.
XII (Plate 114)	Fish	*Trachichthys Australis* (Shaw)	Australian Rough Fish	*Trachichthys australis*	Roughy	This southern Australian endemic has a noxious mucus secreted by its skin which helps protect it from predation.
XII (Plate 115)	Fish	*Lanioperca mordax* (Günth.)	The Skip-jack Pike	*Dinolestes lewini* (Griffith 1834)	Longfin Pike	Resembling a barracuda with its prominent predatory teeth and slender shape, the Longfin Pike is actually a very specialised cardinalfish.
XIII (Plate 122)	Fish	*Trachypterus toenia* (Bloch)	The Southern Silver Ribbon-fish	*Trachipterus arawatae* Clarke 1881	Ribbonfish	Ribbonfish live in surface waters throughout the world oceans where they feed on large concentrations of tiny shrimp and krill.
XIII (Plate 123)	Fish	*Chironectes bifurcatus* (McCoy 1886)	Two-pronged Toad-fish	*Rhycherus filamentosus* (Castelnau 1872)	Tasselled Anglerfish	Southern Australia has the world's greatest diversity of shallow-dwelling anglerfish, like this well camouflaged species that lives on algal-covered reefs.
XIII (Plate 124)	Fish	*Monacanthus Browni* (Rich)	Brown's Tooth-brush Leather-jacket	*Acanthaluteres vittiger* (Castelnau 1873)	Toothbrush Leatherjacket (male)	The Toothbrush Leatherjacket is named for a prominent patch of bristles which develops on either side of the base of the tail in mature males.
XIII (Plate 125)	Fish	*Monacanthus hippocrepis* (Quoy and Gaim)	Horse-shoe-marked Leather-jacket	*Meuschenia hippocrepis*	Horseshoe Leatherjacket	The name of the Horseshoe Leatherjacket is attributable to the distinctive marking on each side of the body, particularly well developed in males.
XIV (Plate 133)	Fish	*Brama Rayi* (Bloch)	Ray's Sea Bream	*Brama brama* (Bonnaterre 1788)	Pomfret	This is a streamlined open water species occurring in all but the coldest parts of the world's oceans.
XIV (Plate 134)	Fish	*Labrichthys Bleekeri* (Cast)	Bleeker's Parrot-fish	*Notolabrus tetricus* (Richardson, 1840)	Bluethroat Wrasse	The most abundant species of wrasse in Victorian coastal waters, this species is often regarded as a nuisance by anglers fishing from rocks along the open coast.
XIV (Plate 135)	Fish	*Hemiramphus intermedius* (Cant.)	Black-finned Half-beak or Sea Gar-fish	*Hyporhamphus melanochir* (Valenciennes, in Cuvier & Valenciennes 1846)	Southern Sea Garfish	Closely related to flying fish, the Garfish is a popular angling and food species taken in bays and estuaries along the southern coast.
XIV (Plate 135)	Fish	*Scomberesox saurus* (Bloch, sp.; var. Forsteri, Cuv. and Val.)	Saury Pike	*Scomberesox saurus*	Saury	The Sauries resemble the tropical Long Toms, but are less attenuate, lack teeth in their jaws and form huge schools that are often attacked by predatory species.
XV (Plate 143)	Fish	*Monacanthus Peronii* (Hollard)	Peron's Leatherjacket	*Acanthaluteres vittiger* (Castelnau 1873)	Toothbrush Leatherjacket (female) apparently a misidentification.	McCoy's description appears to have been based on a Female Toothbrush Leatherjacket. A specimen resembling the figure and marked as being drawn is in the MV collection.

Prodromus Decade	Faunal group	McCoy scientific	McCoy common	Current scientific	Current common	Notes
XV (Plate 144)	Fish	*Echinorhinus spinosus* (Lin.)	Spinous Shark	*Echinorhinus brucus* (Bonnaterre 1788)	Bramble Shark	The specimen used by McCoy as the basis of this account was later designated as a holotype of *Echinorhinus (Rubusqualus) mccoyi* by Whitley (1931).
XV (Plate 145)	Fish	*Regalecus Banksi* (Cuv.)	Banks' Oar-Fish	*Regalecus glesne* Ascanius 1772	Oarfish	The oarfish is probably the longest bony fish in the world, attaining a length of at least 8 m, but reported to reach 17 m.
XVI (Plate 154)	Fish	*Cybium Commersoni* (Lacép)	Commerson's Mackerel	*Scomberomorus commerson*	Narrowbarred Spanish Mackerel	This is a migratory gamefish of the tropical Indo-West Pacific which is only occasionally taken in the easternmost parts of Victorian coastal waters.
XVI (Plate 155)	Fish	*Pelamys Schlegeli* (McCoy)	Melbourne Pelamyde	*Sarda australis* (Macleay 1881)	Australian Bonito	This species has one of the most restricted distributions of the tuna-like fishes, being confined to southeastern Australia, New Zealand and Norfolk Island.
XVII (Plate 163)	Fish	*Labrichthys laticlavius* (Rich)	Broad-striped or Senator Parrot-fish	*Pictilabrus laticlavius*	Senator Wrasse	The Senator Wrasse is a common inhabitant of the algal covered reefs along Australia's exposed southern coasts.
XVII (Plate 164)	Fish	*Heteroscarus Macleayi* (McCoy)	Macleay's Wrasse	*Odax acroptilus* (Richardson, in Richardson and Gray 1846)	Rainbow Cale	The fused jaw teeth and rather deep body of this attractive species has caused it to be incorrectly placed with the tropical parrotfishes by some authors.
XVIII (Plate 172)	Fish	*Seriola Lalandi* Cuv. & Val.	Yellow-Tail	*Seriola lalandi*	Yellowtail Kingfish	The Yellowtail Kingfish is a popular gamefish in many parts of the cool tropical and warm temperate waters of the Southern Hemisphere and North Pacific.
XVIII (Plate 173)	Fish	*Chilodactylus carponemus* Cuv. & Val.	Long-Fingered Chilodactylus	*Nemadactylus valenciennesi* (Whitley, 1937)	Queen Snapper	Confined to southern Australia, the Queen Snapper is only occasionally taken commercially but is considered to have high quality flesh.
XVIII (Plate 174)	Fish	*Chilodactylus carponemus* Cuv. & Val.	Long-Fingered Chilodactylus – Var.	*Nemadactylus valenciennesi* (Whitley, 1937)	Queen Snapper	
XIX (Plate 182)	Fish	*Sillago ciliata* Cuv. & Val.	Plain Whiting	*Sillago ciliata*	Sand Whiting	This whiting is common along the eastern coast of Australia, but rarely enters Victorian waters.
XIX (Plate 183)	Fish	*Temnodon saltator* Linn.	Skipjack	*Pomatomus saltatrix*	Tailor	The Tailor received its common name from the shear-like nature of its powerful jaws.
XIX (Plate 184)	Fish	*Arripis Georgianus* Cuv. & Val.	Roughy	*Arripis georgianus*	Tommy Rough	Extremely similar in appearance to the two species of Australian salmon, the Tommy Rough fails to attain even half their length and is not often seen larger than 25 cm.
XX (Plate 192)	Fish	*Callionymus calauropomus* Ric.	Crook-spined Dragonet	*Callionymus calauropomus*	Common Stinkfish	As might be expected, stinkfish have a strong smelling skin mucus, which also affects the palatability of their flesh.
XX (Plate 193)	Fish	*Neosebastes scorpaenoides* Guich.	Spotted Red Guernet-Perch	*Neosebastes scorpaenoides*	Ruddy Gurnard Perch	All scorpionfishes in southern waters have a painful venom associated with their fin spines, but this is one of the few that is regularly taken by hook and line.
XX (Plate 194)	Fish	*Trachinops caudimaculatus* McCoy	Blotch-tailed Trachinops	*Trachinops caudimaculatus*	Southern Hulafish	First described by McCoy in the *Prodromous*, this is one of the most common species found around rocky reefs in Port Phillip Bay.
I (Plate 1)	Snake	*Pseudechys porphyriacus* Shaw	Black Snake	*Pseudechis porphyriacus* Shaw	Red-bellied Black Snake	

Prodromus Decade	Faunal group	McCoy scientific	McCoy common	Current scientific	Current common	Notes
I (Plate 2)	Snake	*Hoplocephalus superbus* Günth.	Copper-head Snake	*Austrelaps superbus* Gunther	Lowland Copperhead Snake	Copperheads have now been split into three species, two of which occur in Victoria. The specimen illustrated is a Lowland Copperhead Snake.
I (Plate 3)	Snake	*Hoplocephalus curtus* Schl.	Tiger Snake	*Notechis scutatus* (Peters)	Tiger Snake	
II (Plate 11)	Snake	*Hoplocephalus flagellum* McCoy	Little Whip Snake	*Suta flagellum* (McCoy)	Little Whip Snake	
II (Plate 11)	Snake	*Hoplocephalus coronoides* Günth.	White-lipped Snake	*Drysdalia coronoides* (Gunther)	White-lipped Snake	
II (Plate 12)	Snake	*Acanthophis Antarctica* Shaw	Death Adder	*Acanthophis antarctica* (Shaw & Nodder)	Death Adder	
II (Plate 13)	Snake	*Morelia variegata* Gray	Carpet Snake	*Morelia spilota variegata* Gray	Carpet Snake	
III (Plate 23)	Snake	*Diemenia superciliosa* Fisch.	Common Brown Snake	*Pseudonaja textilis* (Dumeril, Bibron & Dumeril)	Common Brown Snake	
III (Plate 23)	Snake	*Diemenia microlepidota*. McCoy	Small-scaled Brown Snake	*Oxyuranus microlepidotus* (McCoy)	Inland Taipan or Fierce Snake	
III (Plate 23)	Snake	*Diemenia aspidorhyncha* McCoy	Shield-fronted Brown Snake	*Pseudonaja nuchalis* Gunther	Western Brown Snake or Gwardar	
IV (Plate 32)	Snake	*Furina bicucullata* McCoy	Two-hooded Furina-Snake	*Pseudonaja textilis* (Dumeril, Bibron & Dumeril)	Common Brown Snake	This description was based on a juvenile specimen.
V (Plate 41)	Lizard	*Hydrosaurus varius* (Shaw)	Lace Lizard	*Varanus varius* (White, ex Shaw)	Lace Monitor	
V (Plate 42)	Frog	*Limnodynastes Tasmaniensis* (Günth.)	Spotted Marsh-Frog	*Limnodynastes tasmaniensis* (Gunther)	Spotted Marsh Frog	
V (Plate 42)	Frog	*Limnodynastes dorsalis* (Gray)	Common Sand-Frog	*Limnodynastes dumerilli*	Pobblebonk	This species has been divided into five subspecies, three of which occur in Victoria. Figure 2 appears to be *Limnodynastes dumerilli insularis* while Figure 2a appears to be intermediate between *L. d. insularis* and *Limnodynastes dumerilli dumerilli*
VI (Plate 51)	Lizard	*Rhodona Officeri* (McCoy)	Victorian Rhodona	*Lerista punctatovittata* (Gunther)	No common name	This was described from a unique live specimen which was apparently never accessed into the Museum collection and is presumably lost.
VI (Plate 52)	Snake	*Vermicella annulata* (Gray)	Black and White Ringed Snake	*Vermicella annulata* (Gray)	Bandy Bandy	
VI (Plate 53)	Frog	*Ranoidea aurea* (Less.)	Green and Golden Bell-Frog	*Litoria raniformis* (Keferstein)	Growling Grass Frog	A member of the *Litoria aurea* complex, and for many years considered a subspecies.
VIII (Plate 72)	Lizard	*Cyclodus gigas* (Bodd)	Northern Blue-tongued Lizard	*Tiliqua scincoides* (White, ex Shaw)	Common Blue-tongue	

Prodromus Decade	Faunal group	McCoy scientific	McCoy common	Current scientific	Current common	Notes
IX (Plate 81)	Lizard	*Physignathus Lesueri* (Gray) var *howitti* (McCoy)	Gippsland Water Lizard	*Physignathus lesueurii howittii* McCoy	Gippsland Water Dragon	
IX (Plate 82, 83)	Tortoise	*Chelymys Macquaria* (Cuv.)	Murray Tortoise	*Emydura macquarii* (Gray)	Short-necked Tortoise	
X (Plate 92, 93)	Tortoise	*Chelodina longicollis* (Shaw)	Long-necked River Tortoise	*Chelodina longicollis* (Shaw)	Long-necked Tortoise	
XI (Plate 101)	Turtle	*Sphargis coriacea* (Linn)	Luth, or Leathery Turtle	*Dermochelys coriacea* (Vandelli)	Luth	
XI (Plate 102)	Lizard	*Trachydosaurus rugosus* (Gray)	Rugged Stump-tail or Shingle-back Lizard	*Trachydosaurus rugosus* (Gray)	Sleepy Lizard	
XI (Plate 103)	Snake	*Typhlops nigrescens* (Gray)	Blackish Australian Worm-Snake	*Ramphotyphlops nigrescens* (Gray)	Blind Snake	
XII (Plate 111)	Lizard	*Grammatophora muricata* (Shaw)	The Blood-sucker	*Amphibolurus muricatus*	Tree Dragon	
XIII (Plate 121)	Lizard	*Grammatophora barbata* (Kaup)	The Bearded Lizard	*Pogona barbata* (Cuvier)	Bearded Dragon or Jew Lizard	Part of *the P. barbata* complex, which has two species in Victoria.
XIV (Plate 131)	Lizard	*Cyclodus nigroluteus* (Quoy and Gaim.)	Southern or Blotched, Blue-tongued Lizard	*Tiliqua nigrolutea* (Quoy and Gaimard)	Blotched Blue-tongue Lizard	
XIV (Plate 132)	Lizard	*Phyllurus Miliusii* (Bory)	Thick-tailed Gecko	*Underwoodisaurus milii* (Bory de St. Vincent)	Thick-tailed Gecko	
XIV (Plate 132)	Lizard	*Diplodactylus marmoratus* (Gray)	Marbled Gecko	*Christinus marmoratus* (Gray)	Marble Gecko	
XV (Plate 141)	Lizard	*Egernia Cunninghami* (Gray)	Spiny-ridged Lizard	*Egernia cunninghami* (Gray)	Cunningham's Skink	
XV (Plate 142)	Snake	*Pseudechys Australis* (Gray)	Brown pseudechys	*Pseudonaja textilis* (Dumeril, Bibron & Dumeril)	Common Brown Snake	McCoy's description, together with the description of *Pseudechis australis* Krefft 1865 of a snake from Fort Bourke, N.S.W., was used by Boulenger in 1896 to erect a new species which he named *Pseudechis cupreus*. McCoy's specimen is in fact a Common Brown Snake, while Krefft's specimen was a *Pseudechis australis* (Mulga or King Brown Snake, a species which has not been recorded from Victoria).
XVI (Plate 151)	Lizard	*Monitor Gouldi* (Gray)	Gould's Monitor Lizard	*Varanus gouldii* (Gray)	Gould's, or Sand Goanna	
XVI (Plate 152)	Lizard	*Pygopus lepidopus* (Lacép)	Pygopus	*Pygopus lepido-podus* (Lacepede)	Common Scaly Foot	
XVI (Plate 153)	Lizard	*Delma Frazeri* (Gray)	Frazer's Delma	*Delma inornata* Kluge	Legless Lizard	
XVII (Plate 161)	Lizard	*Lialis Burtoni* (Gray)	Burton's Lialis	*Lialis burtonis* (Gray)	Burton's Legless Lizard	This species is actually illustrated in Plate 162, but belongs to the text for Plate 161

Prodromus Decade	Faunal group	McCoy scientific	McCoy common	Current scientific	Current common	Notes
XVII (Plate 162)	Lizard	*Aprasia pulchella* (Gray)	Lined Aprasia	*Aprasia striolata* Lutken	Worm Lizard	This species is actually illustrated in Plate 161, but belongs to the text for Plate 162
XVII (Plate 162)	Lizard	*Pseudodelma impar* (Fischer)	Fischer's False Delma	*Delma impar* Fischer	Striped Legless Lizard	Now considered a threatened species within Victoria.
XVIII (Plate 171)	Lizard	*Cyclodus occipitalis* Peters	Broad-Banded or Occipital Blue-Tongue Lizard	*Tiliqua occipitalis* (Peters)	Western Blue-Tongue	
XIX (Plate 181)	Lizard	*Tympanocryptis lineata* Peters	White-Streaked Earless Dragon	*Tympanocryptis lineata pinguicolla* Mitchell	Earless Dragon	Now considered a threatened species within Victoria, no records having reached the museum since 1967.
XX (Plate 191)	Lizard	*Hinulia Whitei* Lacep.	White's Hinulia Lizard	*Egernia whitii* (Lacepede)	White's Skink	
XX (Plate 191)	Lizard	*Hinulia Quoyi* Dum. & Bib.	Quoy's Hinulia Lizard	*Eulamprus tympanum tympanum* (Lonnberg & Andersson)	Water Skink	This species is part of the *Eulamprus quoyi* complex, which has three species in Victoria.
III (Plate 21)	Mammal	*Stenorhynchus leptonyx* de Blainv.	Sea-Leopard Seal	*Hydrurga leptonyx*	Leopard Seal	Common in the Antarctic pack-ice. Stragglers, often in poor condition, are known from Victorian waters, including Port Phillip Bay, from July to October.
III (Plate 22)	Mammal	*Delphinus Novae Zealandiae* Quoy & Gaim.	Yellow-sided Dolphin	*Delphinus delphis*	Common Dolphin	This species strands frequently on the Victorian coast, and is found inside Port Phillip Bay, probably following influxes of fish. The McCoy text makes one minor confusing comment by referring to it as the 'Bottle-nose' of sailors, a different species (*Tursiops truncatus*).
IV (Plate 31)	Mammal	*Euotaria cinerea* Peron	Australian Sea-Bear or Fur-Seal	*Arctocephalus pusillus doriferus*	Australian Fur Seal	McCoy devoted two accounts to this species as the first figure (Plate 31) did not show the typical land habit of the species. Details for Plate 31 duplicate many of those in Plate 71, but the former is more devoted to anatomy than the latter, which includes ecological comments.
VIII (Plate 71)	Mammal	*Euotaria cinerea* (Péron)	Australian Sea-Bear or Fur-Seal	*Arctocephalus pusillus doriferus*	Australian Fur Seal	See previous.
X (Plate 91)	Mammal	*Gymnobelideus Leadbeateri* (McCoy)	Not indicated	*Gymnobelideus leadbeateri*	Leadbeater's Possum	Described by McCoy in 1867. He did not designate a type specimen, but a lectotype was selected by Dixon in 1970. The species is not currently known in the Bass River where it was first located, but occurs in the Central Highlands. Its specific living requirements have led to its present endangered status. It is one of the faunal emblems of Victoria.

The Bryozoa of McCoy's *Prodromus*

Philip Bock[1]

Abstract
Of the 200 plates published in McCoy's *Prodromus of the Zoology of Victoria*, 61 were devoted to bryozoans, documenting 309 species from the Port Phillip region. This major contribution to the knowledge of marine life of the colony was clearly the result of close co-operation between Sir Frederick McCoy and Dr Paul MacGillivray. Although much of this fauna has been revised by later workers, and much more revision is still needed, the account in the *Prodromus* remains the most significant single contribution to the taxonomy of Australian bryozoans. (*The Victorian Naturalist* **118** (6), 2001, 256-265.)

The Polyzoa of the *Prodromus of the Zoology of Victoria*

Numerically, the majority of species figured in the twenty issues of the *Prodromus of the Zoology of Victoria* (MacGillivray 1879-1890), belong to the Phylum Polyzoa, now generally known as the Bryozoa, or Ectoprocta. These descriptions were undertaken by Dr Paul H. MacGillivray, who lived in Bendigo until his death in 1895. MacGillivray commenced his work on Australian bryozoans with a brief paper in the *Transactions of the Philosophical Institute* (MacGillivray 1860a), which was read at a meeting on 3 August, 1859. Clearly, MacGillivray and McCoy were near-contemporaries. Many species described in early papers were collected at Queenscliff, and some were described from material collected by several other people, including Baron Ferdinand von Mueller.

Nine years later, a further paper describing 48 new species was published (MacGillivray 1869). The descriptions and comments in this paper show greater experience and care than the earlier papers, but the descriptions were not accompanied by illustrations. At this stage, MacGillivray announced his intention to provide figures for these species, together with others from Victoria 'in Professor M'Coy's "Memoirs of the Museum" '. As the first Decade of the *Prodromus* was not published until 1878, and the first bryozoan account did not appear until Decade 3, in 1879, it is clear that an extended period of planning and preparation went into the series.

A total of 309 species or varieties of bryozoans was figured and described in the 18 decades. Twenty-six of these species were previously undescribed (Table 1, species indicated as 'n. sp.'). The majority of species defined from the local fauna had been introduced by MacGillivray earlier, in issues of the *Transactions and Proceedings of the Royal Society of Victoria* published shortly before the publication of the relevant issue of the *Prodromus*.

The sequence of descriptions and illustration shows considerable change over time. The plates in Decade 3 are not aesthetically attractive, and each figure is tiny, but there is a large amount of detail. The figures are usually quite accurate and useful in identification. Plates 35 to 38 in Decade 4 are rather less satisfactory, although the same artist prepared the plates. These plates are of encrusting forms, and I believe that a factor contributing to the lack of detail is the difficulty of discerning skeletal structure when it is covered by cuticle. At least a few of the specimens in the collection of Museum Victoria have been calcined, a procedure which involved using a blowpipe to burn the organic material. These specimens have now completely disintegrated, and are useless for observation. However, the material used for the illustrations is generally intact, although some specimens in slides constructed from wood have suffered from 'shell disease', or 'Bind's disease', which can be attributed to reactions between volatiles from the wood and the skeletal material.

In Decade 5, the individual figures are larger, and the rendering, while simpler, is much clearer. A new artist, J. Ripper, prepared the plates in Decades 5 to 13. Commencing in Decade 10, some plates indicate that Dr MacGillivray worked together with J. Ripper in the draughting,

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with lithography by Ripper. The plates in Decades 14 to 20 were draughted by MacGillivray, and lithographed by Ripper. The quality and accuracy of the figures are generally very fine, although some examples are misleading in detail.

The program for documenting the fauna of Victoria was planned beyond the issue of the first twenty Decades, as printed plates for further issues are in the collection of Museum Victoria. These plates include figures of additional bryozoan species, largely of the Order Cyclostomata.

Since about 1980, detailed study of bryozoan material using scanning electron microscopy (SEM) has provided information on skeletal details of bryozoans far greater than was previously achieved with drawings or photographs (Bock 1982). It is now clear that many local species which had been identified using the names of European species are quite distinct, and in several cases are actually complexes of several species. In a small number of cases it has also been possible to determine that the species described from Port Phillip include some synonyms. Nevertheless, the work documented in the *Prodromus* remains a remarkably accurate monograph of the local fauna.

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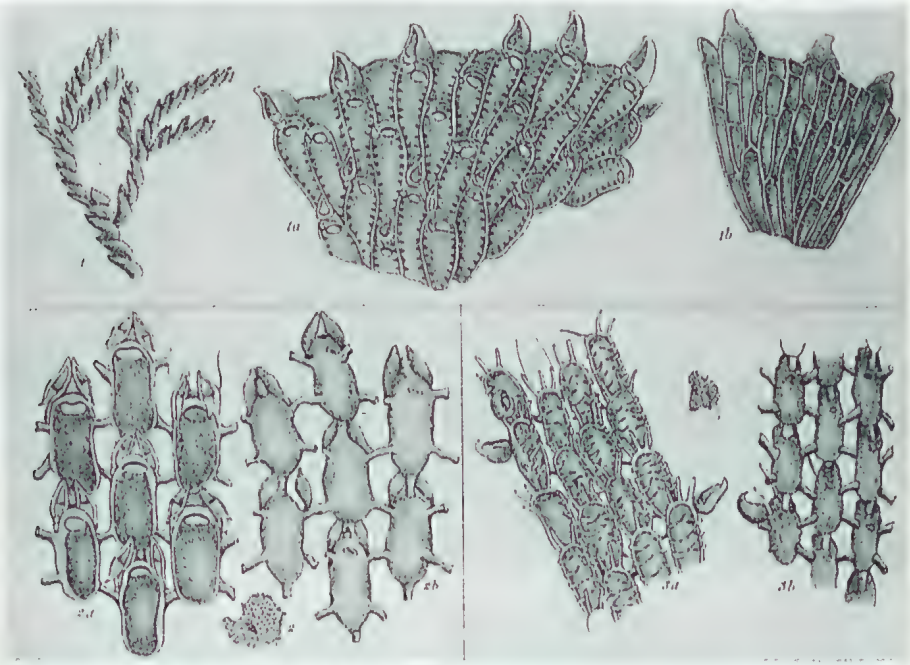

From the *Prodromus of the Zoology of Victoria*, Volume I, Decade V. Plate 46. Lithograph by J. Ripper and A. Bartholomew under the direction of Professor McCoy, printed by Troedel & Co. *Spiralaria florea* (fig. 1); *Diachoris magellanica* (fig. 2); *Diachoris spinigera* (fig. 3)

Table 1. Listing of the bryozoans described in the *Prodromus of the Zoology of Victoria*, with current accepted names for most of the species. In a large number of cases, progress of revision is still inadequate to specify a current name, and the column is left blank. The Location entry is quoted from each entry in the *Prodromus*. Most species are now known to have a wider distribution, although a number have not been recorded in subsequent literature. n.sp., new species; 'PPH', Port Phillip Heads.

Plate	Name Used	Remarks	Current Name	Author	Locality
Pl. 24, Fig. 1	*Catenicella margaritacea*		*Orthoscuticella margaritacea*	(Busk, 1852)	Vic.
Pl. 24, Fig. 2	*Catenicella plagiostoma*		*Scuticella plagiostoma*	(Busk, 1852)	
Pl. 24, Fig. 3	*Catenicella ventricosa*		*Orthoscuticella ventricosa*	(Busk, 1852)	
Pl. 24, Fig. 4	*Catenicella hastata*		*Costaticella hastata*	(Busk, 1852)	Queenscliff, Western Port
Pl. 24, Fig. 5	*Catenicella rufa*		*Cribricellina rufa*	(MacGillivray, 1869)	
Pl. 24, Fig. 6	*Catenicella cribraria*		*Paracribricellina cribraria*	(Busk, 1852)	Queenscliff, Western Port
Pl. 24, Fig. 7	*Catenicella alata*		*Pterocella vesiculosa*	(Lamarck, 1816)	Queenscliff
Pl. 24, Fig. 8	*Catenicella lorica*		*Orthoscuticella lorica*	(Busk, 1852)	Queenscliff
Pl. 24, Fig. 9	*Catenicella formosa*		*Catenicella formosa*	Busk, 1852	Queenscliff, C.Schanck
Pl. 24, Fig. 10	*Catenicella elegans*		*Catenicella elegans*	Busk, 1852	
Pl. 24, Fig. 11	*Catenicella perforata*		*Cornuticella perforata*	(Busk, 1852)	
Pl. 24, Fig. 12	*Catenicella buskii*		*Catenicella buskii*	Wyville Thomson, 1858	
Pl. 24, Fig. 13	*Catenicella hannafordi*		*Catenicella hannafordi*	MacGillivray, 1869	Portland
Pl. 24, Fig. 14	*Catenicella crystallina*		*Scalicella crystallina*	(W.Thomson, 1858)	
Pl. 24, Fig. 15	*Catenicella carinata*		*Pterocella scutella*	(Hutton, 1891)	
Pl. 24, Fig. 16	*Catenicella aurita*		*Claviporella aurita*	(Busk, 1852)	
Pl. 24, Fig. 17	*Catenicella geminata*		*Claviporella geminata*	(Wyville Thomson, 1858)	
No Fig.	*Catenicella cornuta*		*Cornuticella cornuta*	(Busk, 1852)	
No Fig.	*Catenicella intermedia*		*Orthoscuticella? intermedia*	(MacGillivray, 1869)	
Pl. 25, Fig. 1	*Membranipora membranacea*		*Membranipora membranacea*	(Linnaeus, 1767)	
Pl. 25, Fig. 2	*Membranipora perforata*		*Micropora stenostoma*	(Busk, 1854)	Queenscliff
Pl. 25, Fig. 3	*Membranipora ciliata*		*Chaperia acanthina*	(Lamouroux, 1825)	Queenscliff, Williamstown
Pl. 25, Fig. 4	*Membranipora mamillaris*		*Thairopora mamillaris*	(Lamouroux, 1816) ?	Queenscliff
Pl. 25, Fig. 5,6	*Membranipora umbonata*				Queenscliff
Pl. 25, Fig. 7	*Membranipora pilosa*		*Electra pilosa*	(Linnaeus, 1767)	
Pl. 25, Fig. 8	*Membranipora cervicornis*		*Chaperiopsis cervicornis*	(Busk, 1854)	Williamstown
Pl. 26, Fig. 1	*Membranipora dispar*		*Thairopora dispar*	(MacGillivray, 1869)	Portland
Pl. 26, Fig. 2	*Membranipora woodsii*		*Diploporella woodsii?*	(MacGillivray, 1869)	Portland
Pl. 26, Fig. 3	*Membranipora lineata*		*Valdemunitella pyrula*	(Hincks, 1881)	Schnapper Point, Port Fairy
Pl. 26, Fig. 4	*Membranipora rosselii*				
Pl. 26, Fig. 5,6	*Membranipora lacroixii*		*Conopeum aciculatum*	(MacGillivray, 1891)	Queenscliff, Point Cook, Brighton
Pl. 35, Fig. 1	*Lepralia circinata*		*Phonicosia circinata*	(MacGillivray, 1869)	Queenscliff
Pl. 35, Fig. 2	*Lepralia cecilii*		*Arthropoma cecilii*	(Audouin, 1826)	Queenscliff, Warrnambool
Pl. 35, Fig. 3	*Lepralia diaphana*	n.sp.	*Escharella diaphana*	(MacGillivray, 1879)	Queenscliff, Warrnambool
Pl. 35, Fig. 4	*Lepralia marsupium*		*Aimulosia marsupium*	(MacGillivray, 1869)	
Pl. 35, Fig. 5	*Lepralia subimmersa*	n.sp.	*Calyptotheca subimmersa*	(MacGillivray, 1879)	Warrnambool
Pl. 35, Fig. 6	*Lepralia anceps*	n.sp.	*Calyptotheca anceps*	(MacGillivray, 1879)	Warrnambool

Plate	Name Used	Remarks	Current Name	Author	Locality
Pl. 35, Fig. 7	*Lepralia maplestonei*	n.sp.	*Schizosmittina maplestonei*	(MacGillivray, 1879)	Williamstown
Pl. 36, Fig. 1	*Lepralia vittata*		*Chorizopora vittata*	(MacGillivray, 1869)	Western Port
Pl. 36, Fig. 2	*Lepralia brogniartii*		*Chorizopora brongniartii*	(Audouin, 1826)	Queenscliff
Pl. 36, Fig. 3	*Membranipora perforata*		*Micropora stenostoma*	(Busk, 1854)	
Pl. 36, Fig. 4	*Lepralia elegans*		*Hippoporina elegans*	(MacGillivray, 1860)	Wiiliamstown, Queenscliff
Pl. 36, Fig. 5,6	*Lepralia pertusa*				Hobsons Bay
Pl. 36, Fig. 7	*Lepralia malusii*				Queenscliff
Pl. 36, Fig. 8	*Lepralia lunata*		*Calloporina lunata*	(MacGillivray, 1860)	Queenscliff
Pl. 37, Fig. 1	*Lepralia ciliata*				Port Fairy, Warrnambool
Pl. 37, Fig. 2	*Lepralia trifolium*		*Onychoblestrum propinquum*	(Waters, 1885)	Queenscliff, Williamstown, Western Port
Pl. 37, Fig. 3	*Lepralia cheilodon*		*Parasmittina cheilodon*	(MacGillivray, 1869)	Williamstown
Pl. 37, Fig. 4	*Lepralia canaliculata*		*Calloporina canaliculata*	(MacGillivray, 1860)	Queenscliff
Pl. 37, Fig. 5	*Lepralia larvalis*		*Didymosella larvalis*	(MacGillivray, 1869)	Williamstown
Pl. 37, Fig. 6	*Lepralia diadema*		*Calloporina diadema*	(MacGillivray, 1869)	Williamstown, Queenscliff, Warrnambool
Pl. 37, Fig. 7	*Lepralia papillifera*		*Smittina papillifera*	(MacGillivray, 1869)	Williamstown
Pl. 37, Fig. 8	*Lepralia ellerii*		*Mucropetraliella ellerii*	(MacGillivray, 1869)	Williamstown, Warrnambool
Pl. 38, Fig. 1,2	*Lepralia monoceros*		*Arachnopusia unicornis*	(Hutton, 1873)	Queenscliff,Warrnambool
Pl. 38, Fig. 3	*Lepralia excavata*		*Escharoides excavata*	(MacGillivray, 1860)	Queenscliff
Pl. 38, Fig. 4	*Lepralia vitrea*	n.sp.	*Schizosmittina vitrea*	(MacGillivray, 1879)	Williamstown
Pl. 38, Fig. 5	*Lepralia megasoma*		*Turbicellepora megasoma*	(MacGillivray, 1869)	Queenscliff
Pl. 38, Fig. 6	*Lepralia schizostoma*		*Stylopoma schizostoma*	(MacGillivray, 1869)	Williamstown, Queenscliff
Pl. 38, Fig. 7	*Lepralia botryoides*	n.sp.	*Schizosmittina vitrea*	(MacGillivray, 1879)	Williamstown
Pl. 38, Fig. 8	*Lepralia ferox*		*Hiantopora ferox*	(MacGillivray, 1869)	Williamstown, Queenscliff
Pl. 38, Fig. 9	*Lepralia pellucida*	n.sp.			Williamstown, Queenscliff
Pl. 39, Fig. 1	*Crisia edwardsiana*		*Bicrisia edwardsiana*	(d'Orbigny, 1847)	Williamstown
Pl. 39, Fig. 2	*Crisia biciliata*		*Bicrisia biciliata*	(MacGillivray, 1869)	Williamstown, Warrnambool
Pl. 39, Fig. 3	*Crisia acropora*		*Crisia acropora*	Busk, 1852	Williamstown, Queenscliff
Pl. 39, Fig. 4	*Crisia setosa*		*Crisia setosa*	MacGillivray, 1869	Williamstown, Queenscliff
Pl. 39, Fig. 5	*Crisia tenuis*	n.sp.	*Crisia tenuis*	MacGillivray, 1879	Queenscliff
Pl. 45, Fig. 1	*Flustra denticulata*		*Hincksinoflustra denticulata*	(Busk, 1852)	Queenscliff
Pl. 45, Fig. 2	*Carbasea episcopalis*		*Euthyroides episcopalis*	(Busk, 1852)	Queenscliff, King I.
Pl. 45, Fig. 3	*Carbasea dissimilis*		*Bugularia dissimilis*	(Busk, 1852)	Queenscliff, King I.
Pl. 45, Fig. 4	*Carbasea indivisa*		*Carbasea indivisa*	Busk, 1852	Queenscliff, Portland
Pl. 45, Fig. 5	*Carbasea elegans*		*Carbasea elegans*	Busk, 1852	Queenscliff, Portland
Pl. 45, Fig. 6	*Carbasea pisciformis*		*Carbasea pisciformis*	Busk, 1852	Queenscliff, Portland
Pl. 46, Fig. 1	*Spiralaria florea*		*Spiralaria florea*	Busk, 1861	Queenscliff
Pl. 46, Fig. 2	*Diachoris magellanica*		*Beania magellanica*	(Busk, 1852)	Portland
Pl. 46, Fig. 3	*Diachoris spinigera*		*Beania spinigera*	(MacGillivray, 1860)	Queenscliff, Portland
Pl. 46, Fig. 4	*Dimetopia spicata*		*Dimetopia barbata*	(Lamouroux, 1816)	Queenscliff, Portland
Pl. 46, Fig. 5	*Dimetopia cornuta*		*Dimetopia cornuta*	Busk, 1852	Queenscliff, Portland
Pl. 46, Fig. 6	*Didymia simplex*		*Didymozoum simplex*	(Busk, 1852)	Queenscliff, Portland

Plate	Name Used	Remarks	Current Name	Author	Locality
Pl. 46, Fig. 7	*Calwellia bicornis*		*Calwellia bicornis*	(Wyville Thomson, 1858)	Queenscliff
Pl. 47, Fig. 1	*Dictyopora cellulosa*		*Adeona cellulosa*	(MacGillivray, 1869)	Queenscliff
Pl. 48, Fig. 1	*Eschara obliqua*		*Parmularia reniformis (?)*	(Kirchenpauer, 1869)	Schnapper Point
Pl. 48, Fig. 2	*Eschara dispar*		*Laminopora dispar*	(MacGillivray, 1869)	Queenscliff
Pl. 48, Fig. 3	*Eschara gracilis*		*Porina gracilis*	(Lamarck, 1816)	Queenscliff
Pl. 48, Fig. 4	*Eschara platalea*		*Adeonella lichenoides*	(Lamarck, 1816)	Queenscliff
Pl. 48, Fig. 5	*Eschara quadrata*	n.sp.	*Emballotheca quadrata*	(MacGillivray, 1880)	Queenscliff, Portland
Pl. 48, Fig. 6,7	*Eschara mucronata*		*Adeonellopsis sulcata*	(Milne Edwards, 1836)	Queenscliff, Schnapper Point
Pl. 48, Fig. 8	*Caleschara denticulata*		*Caleschara denticulata*	(MacGillivray, 1869)	Queenscliff, Schnapper Point
Pl. 49, Fig. 1	*Cellaria fistulosa* var. *australis*	n.var.	*Cellaria australis*	MacGillivray, 1880	Queenscliff, Portland
Pl. 49, Fig. 2	*Cellaria hirsuta*		*Cellaria pilosa*	(Kirchenpauer, 1869)	Queenscliff, Portland
Pl. 49, Fig. 3	*Cellaria tenuirostris*		*Cellaria tenuirostris*	(Busk, 1852)	Queenscliff, Wilsons Prom.
Pl. 49, Fig. 4	*Cellaria gracilis*				Queenscliff, Wilsons Prom.
Pl. 49, Fig. 5	*Nellia oculata*		*Nellia tenella*	(Lamarck, 1816)	Queenscliff
Pl. 49, Fig. 6	*Tubucellaria hirsuta*		*Margaretta barbata*	(Lamarck, 1816)	Queenscliff, Portland
Pl. 57, Fig. 1	*Biflustra perfragilis*	n.n.	*Biflustra perfragilis*	MacGillivray, 1881	PPH, King I.
Pl. 57, Fig. 2	*Biflustra delicatula*		*Biflustra savartii*	(Audouin, 1826)	Queenscliff
Pl. 58, Fig. 1	*Cellularia cuspidata*		*Bugulopsis monotrypa*	(Busk, 1852)	Queenscliff
Pl. 58, Fig. 2	*Menipea crystallina*		*Emma rotunda*	Hastings, 1939	Queenscliff
Pl. 58, Fig. 3	*Menipea cyathus*		*Monartron cyathus*	(Wyville Thomson, 1858)	Queenscliff
Pl. 58, Fig. 4	*Menipea cervicornis*		*Emma cervicornis*	(MacGillivray, 1869)	Queenscliff
Pl. 58, Fig. 5	*Menipea tricellata*		*Emma tricellata*	Busk, 1852	Queenscliff
Pl. 58, Fig. 6	*Menipea buskii*		*Emma buskii*	(Wyville Thomson, 1858)	Queenscliff
Pl. 59, Fig. 1	*Bicellaria tuba*		*Cornucopina tuba*	(Busk, 1852)	Queenscliff, Portland
Pl. 59, Fig. 2,3	*Bicellaria grandis*		*Cornucopina grandis*	(Busk, 1852)	Queenscliff, C.Otway
Pl. 59, Fig. 4	*Bicellaria ciliata*		*Bicellariella ciliata*	(Linnaeus, 1758)	Queenscliff, Portland
Pl. 59, Fig. 5	*Bicellaria turbinata*		*Bicellariella turbinata*	(MacGillivray, 1869)	Queenscliff
Pl. 59, Fig. 6	*Stirparia annulata*		*Caulibugula annulata*	(Maplestone, 1879)	C.Otway, Portland
Pl. 59, Fig. 7	*Bugula neritina*		*Bugula neritina*	(Linnaeus, 1758)	Hobsons Bay, Queenscliff, Warrnambool
Pl. 60, Fig. 1	*Steganoporella magnilabris*		*Steginoporella truncata*	Harmer, 1900	Queenscliff, Portland
Pl. 60, Fig. 2	*Petralia undata*		*Petralia undata*	(MacGillivray, 1869)	Queenscliff, Portland
Pl. 66, Fig. 1	*Dictyopora grisea*		*Adeona grisea*	Lamouroux, 1816	PPH
Pl. 66, Fig. 2	*Dictyopora albida* var. *avicularis*		*Adeona albida*	Kirchenpauer, 1880	PPH
Pl. 67.	*Dictyopora wilsoni*		*Adeona wilsoni*	(MacGillivray, 1881)	PPH
Pl. 68, Fig. 1	*Idmonea milneana*				PPH
Pl. 68, Fig. 2	*Idmonea australis*	n.sp.	*Idmidronea australis*	(MacGillivray, 1882)	PPH
Pl. 68, Fig. 3	*Idmonea radians*		*Mesonea radians*	(Lamarck, 1816)	Queenscliff, Williamstown, Portland
Pl. 78, Fig. 1	*Bugula robusta*		*Bugula robusta*	MacGillivray, 1869	Western Port
Pl. 78, Fig. 2	*Bugula cucullata*		*Bugula cucullata*	Busk, 1867	Queenscliff, Portland
Pl. 78, Fig. 3	*Bugula dentata*		*Bugula dentata*	(Lamouroux, 1816)	Queenscliff, Hobsons Bay

Plate	Name Used	Remarks	Current Name	Author	Locality
Pl. 78, Fig. 4	*Bugula avicularia*		*Bugula avicularia*	(Linnaeus, 1758)	Hobsons Bay
Pl. 89, Fig. 1	*Catenicella intermedia*		*Orthoscuticella? intermedia*	(MacGillivray, 1869)	PPH
Pl. 89, Fig. 2	*Catenicella amphora*		*Orthoscuticella amphora*	(Busk, 1852)	PPH
Pl. 89, Fig. 3	*Catenicella wilsoni*		*Orthoscuticella wilsoni*	(MacGillivray, 1881)	PPH
Pl. 89, Fig. 4	*Catenicella pulchella*		*Strongylopora pulchella*	(Maplestone, 1880)	PPH, Queenscliff
Pl. 89, Fig. 5	*Catenicella utriculus*	n.sp.	*Catenicella utriculus*	MacGillivray, 1884	Warrnambool
Pl. 90, Fig. 1	*Catenicella fusca*	n.sp.	*Catenicella fusca*	MacGillivray, 1884	Queenscliff
Pl. 90, Fig. 2	*Catenicella umbonata*		*Scalicella umbonata*	(Busk, 1852)	PPH
Pl. 90, Fig. 3	*Catenicella cornuta*		*Cornuticella cornuta*	(Busk, 1852)	Queenscliff
Pl. 94.	*Opercula of Retepora spp.*				
Pl. 95, Fig. 1-6	*Retepora porcellana*		*Reteporella porcellana*	(MacGillivray, 1869)	PPH
Pl. 95, Fig. 7-11	*Retepora avicularis*		*Phidolopora avicularis*	(MacGillivray, 1883)	PPH
Pl. 95, Fig. 12-16	*Retepora fissa*		*Reteporella fissa*	(MacGillivray, 1869)	
Pl. 96, Fig. 1-3	*Retepora monilifera* form *monilifera*		*Triphyllozoon moniliferum*	(MacGillivray, 1860)	PPH, Portland, Warrnambool
Pl. 96, Fig. 4-8	*Retepora monilifera* form *munita*		*Triphyllozoon munitum*	(Hincks, 1878)	
Pl. 97, Fig. 1-3	*Retepora monilifera* form *umbonata*		*Triphyllozoon munitum*	(Hincks, 1878)	PPH
Pl. 97, Fig. 4-6	*Retepora formosa*		*Triphyllozoon formosum*	(MacGillivray, 1884)	PPH
Pl. 97, Fig. 7	*Retepora carinata*		*Reteporella carinata*	(MacGillivray, 1884)	PPH
Pl. 98, Fig. 1-5	*Retepora phoenicea*		*Iodictyum phoeniceum*	(Busk, 1854)	PPH, Portland, King I.
Pl. 98, Fig. 6-7	*Retepora aurantiaca*		*Reteporella aurantiaca*	(MacGillivray, 1883)	PPH
Pl. 99, Fig. 1-3	*Retepora granulata*		*Reteporella granulata*	(MacGillivray, 1869)	PPH
Pl. 99, Fig. 4-8	*Retepora tessellata*		*Schizoretepora tessellata*	(Hincks, 1878)	PPH
Pl. 99, Fig. 9	*Retepora serrata*		*Iodictyum serratum*	(MacGillivray, 1883)	PPH
Pl. 105, Fig. 1	*Cellaria rigida*		*Cellaria rigida*	MacGillivray, 1885	PPH
Pl. 105, Fig. 2	*Tubucellaria cereoides*		*Margaretta watersi*	(Canu & Bassler, 1930)	PPH
Pl. 105, Fig. 3-4	*Urceolipora dentata*		*Malakosaria dentata*	(MacGillivray, 1885)	PPH
Pl. 105, Fig. 5-7	*Urceolipora nana*		*Urceolipora nana*	MacGillivray, 1881	PPH
Pl. 106, Fig. 1	*Amphiblestrum punctigerum*				PPH
Pl. 106, Fig. 2	*Amphiblestrum flemingii*				PPH
Pl. 106, Fig. 3	*Amphiblestrum permunitum*		*Parellisina falcata*	(MacGillivray, 1869)	PPH, Portland
Pl. 106, Fig. 4	*Pyripora crassa*		*Mychoplectra crassa*	(MacGillivray, 1869)	Queenscliff
Pl. 106, Fig. 5	*Pyripora catenularia*		*Mychoplectra crassa*	(MacGillivray, 1869)	PPH, Brighton
Pl. 106, Fig. 6	*Pyripora polita*		*Mychoplectra pocula*	(Hincks, 1880)	Queenscliff
Pl. 106, Fig. 7	*Electra flagellum*		*Electra flagellum*	(MacGillivray, 1882)	Queenscliff
Pl. 106, Fig. 8	*Bathypora porcellana*		*Bathypora porcellana*	(MacGillivray, 1885)	Portland
Pl. 106, Fig. 9	*Biflustra papulifera*		*Crassimarginatella papulifera*	(MacGillivray, 1882)	PPH
Pl. 106, Fig. 10	*Biflustra bimamillata*				
Pl. 107, Fig. 1	*Catenicellopsis pusilla*		*Claviporella pusilla*	(Wilson, 1880)	Spring Ck (Geelong)
Pl. 107, Fig. 2	*Catenicellopsis delicatula*		*Catenicellopsis delicatula*	(Wilson, 1880)	PPH, Spring Ck (Geelong)
Pl. 107, Fig. 3	*Calpidium ponderosum*		*Calpidium ponderosum*	(Goldstein, 1880)	PPH
Pl. 108, Fig. 1	*Calpidium ornatum*		*Calpidium ornatum*	Busk, 1852	PPH

Plate	Name Used	Remarks	Current Name	Author	Locality
Pl. 108, Fig. 2	*Chlidonia daedala*		*Chlidonia pyriformis*	(Bertolini, 1810)	
Pl. 116, Fig. 1	*Beania mirabilis*		*Beania mirabilis*	Johnston, 1840	PPH
Pl. 116, Fig. 2,4	*Mucronella tricuspis*		*Exochella tricuspis*	(Hincks, 1881)	PPH, Portland
Pl. 116, Fig. 3	*Mucronella laevis*		*Escharella teres*	(Hincks, 1881)	PPH
Pl. 116, Fig. 5-8	*Mucronella vultur*		*Mucropetraliella vultur*	(Hincks, 1882)	PPH, Portland, Warrnambool
Pl. 116, Fig. 9	*Cyclicopora longipora*		*Cyclicopora longipora*	(MacGillivray, 1883)	PPH
Pl. 117, Fig. 1,2	*Beania decumbens*		*Beania decumbens*	MacGillivray, 1882	PPH
Pl. 117, Fig. 3	*Beania costata*		*Beania discodermiae*	(Ortmann, 1890)	PPH
Pl. 117, Fig. 4,5	*Beania crotali*		*Beania crotali*	(Busk, 1852)	PPH, Portland
Pl. 117, Fig. 6-8	*Beania radicifera*		*Hiantopora radicifera*	(Hincks, 1881)	PPH
Pl. 117, Fig. 9	*Amphiblestrum patellarium*		*Mollia patellaria*	(Moll, 1803)	PPH
Pl. 118, Fig. 1-5	*Hornera foliacea*		*Hornera foliacea*	(MacGillivray, 1869)	PPH, Portland, Western Port
Pl. 118, Fig. 6-8	*Hornera robusta*		*Hornera robusta*	(MacGillivray, 1869)	PPH
Pl. 126, Fig. 1	*Maplestonia cirrata*		*Maplestonia cirrata*	MacGillivray, 1885	PPH, Portland, Warrnambool
Pl. 126, Fig. 3	*Scrupocellaria cyclostoma*		*Scrupocellaria cyclostoma*	Busk, 1852	PPH, Portland
Pl. 126, Fig. 4-5	*Scrupocellaria obtecta*				PPH
Pl. 126, Fig. 6-7	*Scrupocellaria cervicornis*				PPH
Pl. 126, Fig. 8	*Scrupocellaria scrupea*				PPH, Portland
Pl. 126, Fig. 9	*Scrupocellaria ornithorhynchus*		*Scrupocellaria ornithorhynchus*	Thomson, 1858	PPH
Pl. 127, Fig. 1	*Membranipora pyrula*		*Valdemunitella pyrula*	(Hincks, 1881)	PPH, Portland
Pl. 127, Fig. 2	*Membranipora corbula*		*Corbulella corbula*	(Hincks, 1880)	PPH, Portland
Pl. 127, Fig. 3	*Membranipora inarmata*		*Gregarinidra inarmata*	(Hincks, 1881)	PPH
Pl. 127, Fig. 4	*Membranipora pectinata*		*Gregarinidra inarmata*	(Hincks, 1881)	PPH
Pl. 127, Fig. 5	*Membranipora serrata*		*Gregarinidra serrata*	(MacGillivray, 1869)	PPH
Pl. 127, Fig. 6	*Membranipora ciliata*		*Chaperia acanthina*	(Lamouroux, 1825)	Portland
Pl. 127, Fig. 7	*Amphiblestrum albispinum*		*Chaperia albispina*	(MacGillivray, 1882)	Queenscliff, Portland
Pl. 127, Fig. 8	*Membranipora spinosa*		*Chaperia acanthina*	(Lamouroux, 1825)	
Pl. 128, Fig. 1	*Cellepora speciosa*	n.sp.	*Celleporaria speciosa*	(MacGillivray, 1886)	PPH
Pl. 128, Fig. 2	*Cellepora serratirostris*		*Celleporaria serratirostris*	(MacGillivray, 1885)	PPH
Pl. 128, Fig. 3	*Cellepora tridenticulata*				PPH, Warrnambool
Pl. 136, Fig. 1	*Caberea rudis*		*Amastigia rudis*	Busk, 1852	PPH, Portland
Pl. 136, Fig. 2	*Caberea grandis*		*Caberea dichotoma*	Lamouroux, 1816	PPH
Pl. 136, Fig. 3	*Canda arachnoides*		*Canda arachnoides*	Lamouroux, 1816	PPH, Portland
Pl. 136, Fig. 4	*Canda tenuis*		*Canda tenuis*	MacGillivray, 1885	PPH
Pl. 137, Fig. 1,5	*Caberea darwinii*		*Caberea helicina*	Hastings, 1943	PPH, Portland
Pl. 137, Fig. 2-4	*Caberea glabra*		*Caberea glabra*	MacGillivray, 1886	PPH
Pl. 137, Fig. 6	*Aetea dilatata*		*Aetea dilatata*	(Busk, 1851)	PPH
Pl. 137, Fig. 7	*Aetea anguina*		*Aetea anguina*	(Linnaeus, 1758)	PPH
Pl. 138, Fig. 1	*Schizoporella punctigera*		*Parkermavella punctigera*	(MacGillivray, 1883)	PPH
Pl. 138, Fig. 2	*Schizoporella lata*				PPH
Pl. 138, Fig. 3	*Schizoporella triangula*		*Calyptotheca triangula*	(Hincks, 1881)	PPH

Plate	Name Used	Remarks	Current Name	Author	Locality
Pl. 138, Fig. 4	*Schizoporella daedala*		*Chiastosella daedala*	(MacGillivray, 1887)	
Pl. 138, Fig. 5	*Schizoporella subsinuata*				PPH
Pl. 138, Fig. 6,7	*Schizoporella ridleyi*		*Buffonellodes ridleyi*	(MacGillivray, 1883)	PPH
Pl. 138, Fig. 8	*Schizoporella arachnoides*		*Lacerna arachnoides*	(MacGillivray, 1883)	PPH
Pl. 138, Fig. 9	*Schizoporella cryptostoma*		*Stephanollona cryptostoma*	(MacGillivray, 1885)	PPH
Pl. 138, Fig. 10	*Gemellipora striatula*		*Trypostega venusta*	(Norman, 1864)	PPH
Pl. 146, Fig. 1	*Catenicella gemella*		*Pterocella gemella*	(MacGillivray, 1887)	PPH
Pl. 146, Fig. 2	*Catenicella urnula*		*Orthoscuticella urnula*	(MacGillivray, 1887)	PPH
Pl. 146, Fig. 3	*Catenicella gracilenta*				PPH
Pl. 146, Fig. 4	*Catenicella venusta*		*Catenicella venusta*	MacGillivray, 1887	PPH
Pl. 146, Fig. 5	*Catenicella pulchra*				PPH
Pl. 146, Fig. 6	*Catenicella imperforata*				PPH
Pl. 147, Fig. 1	*Diastopora cristata*				PPH
Pl. 147, Fig. 2	*Diastopora capitata*				PPH
Pl. 147, Fig. 3	*Diastopora bicolor*				PPH
Pl. 147, Fig. 4	*Diastopora sarniensis*		*Plagioecia sarniensis*	(Norman, 1864)	PPH
Pl. 147, Fig. 5	*Diastopora patina*		*Plagioecia patina*	(Lamarck, 1816)	PPH
Pl. 148, Fig. 1	*Cellepora megasoma*		*Turbicellepora redoutei*	(Audouin, 1826)	PPH
Pl. 148, Fig. 2	*Cellepora costata*		*Celleporina costata*	(MacGillivray, 1869)	PPH, Portland, Warrnambool, Wilsons Prom.
Pl. 148, Fig. 3	*Cellepora rota*				PPH
Pl. 148, Fig. 5-6	*Cellepora costazei* var. *spatula*	*n.var*	*Celleporina spatula*	(MacGillivray, 1887)	PPH
Pl. 148, Fig. 7	*Cellepora platalea*		*Celleporina platalea*	(MacGillivray, 1869)	PPH
Pl. 148, Fig. 8	*Cellepora glomerata*		*Osthimosia glomerata?*	(MacGillivray, 1887)	PPH
Pl. 148, Fig. 9	*Cellepora vitrea*				PPH
Pl. 148, Fig. 10	*Cellepora tiara*				PPH
Pl. 148, Fig. 11	*Cellepora benemunita*	n.sp	*Osthimosia benemunita*	(MacGillivray, 1887)	PPH
Pl. 156, Fig. 1,2	*Lagenipora tuberculata*		*Exechonella tuberculata*	(MacGillivray, 1883)	PPH
Pl. 156, Fig. 3	*Lagenipora nitens*		*Celleporina platalea*	(MacGillivray, 1869)	PPH
Pl. 156, Fig. 4-10	*Lekythopora hystrix*		*Lekythopora hystrix*	MacGillivray, 1883	PPH
Pl. 156, Fig. 11-13	*Poecilopora anomola*		*Poecilopora anomala*	MacGillivray, 1886	PPH
Pl. 157, Fig. 1	*Fasciculipora gracilis*		*Hastingsia gracilis*	(MacGillivray, 1883)	PPH
Pl. 157, Fig. 2	*Fasciculipora bellis*				PPH
Pl. 157, Fig. 3	*Fasciculipora fruticosa*				PPH
Pl. 157, Fig. 4	*Fasciculipora ramosa*				Portland
Pl. 158, Fig. 1	*Farciminaria aculeata*		*Farciminaria aculeata*	Busk, 1852	PPH
Pl. 158, Fig. 2-4	*Farciminaria uncinata*		*Farciminaria uncinata*	Hincks, 1884	PPH
Pl. 158, Fig. 5	*Farciminaria simplex*		*Farciminaria simplex*	MacGillivray, 1886	PPH
Pl. 158, Fig. 6-8	*Bracebridgia pyriformis*		*Bracebridgia pyriformis*	(Busk, 1884)	
Pl. 165, Fig. 1	*Cellepora simplex*	n.sp.	*Celleporaria simplex*	(MacGillivray, 1888)	PPH

Plate	Name Used	Remarks	Current Name	Author	Locality
Pl. 165, Fig. 2	*Cellepora diadema*	n.sp			PPH
Pl. 165, Fig. 3	*Cellepora spicata*	n.sp	*Celleporaria spicata*	(MacGillivray, 1888)	PPH
Pl. 165, Fig. 4	*Cellepora cidaris*	n.sp	*Celleporaria columnaris*	(Busk, 1881)	PPH
Pl. 165, Fig. 5	*Cellepora bispinata*		*Celleporaria bispinata*	(Busk, 1854)	PPH, Warrnambool, Portland
Pl. 166, Fig. 1	*Cellepora verrucosa*	n.sp.	*Celleporaria verrucosa*	(MacGillivray, 1888)	Portland
Pl. 166, Fig. 2	*Cellepora foliata*	n.sp	*Celleporaria foliata*	(MacGillivray, 1888)	Portland
Pl. 166, Fig. 3	*Cellepora intermedia*		*Celleporaria intermedia*	(MacGillivray, 1869)	Queenscliff
Pl. 166, Fig. 4	*Cellepora prolifera*	n.sp	*Celleporaria prolifera*	(MacGillivray, 1888)	Portland
Pl. 167, Fig. 1	*Cellepora albirostris*				PPH
Pl. 167, Fig. 2	*Cellepora fusca*		*Celleporaria fusca*	(Busk, 1854)	Portland
Pl. 167, Fig. 3	*Cellepora lirata*	n.sp	*Celleporaria cristata*	(Lamarck, 1816)	PPH
Pl. 167, Fig. 4	*Cellepora magnirostris*	n.sp	*Celleporaria magnirostris*	(MacGillivray, 1888)	PPH
Pl. 168.	Chitinous parts of *Cellepora* spp.				
Pl. 175, Fig. 1	*Tessaradoma magnirostris*		*Tubiporella magnirostris*	(MacGillivray, 1883)	PPH
Pl. 175, Fig. 2	*Microporella diadema* var. *lunipuncta*		*Calloporina lunipuncta*	(MacGillivray, 1885)	
Pl. 175, Fig. 3	*Microporella diadema* var. *longispina*				
Pl. 175, Fig. 4	*Microporella diadema* var. *lata*		*Calloporina lunata*	(MacGillivray, 1860)	
Pl. 175, Fig. 5	*Microporella diadema* var. *canaliculata canaliculata*		*Calloporina canaliculata*	(MacGillivray, 1860)	
Pl. 175, Fig. 6	*Microporella renipuncta*		*Calloporina renipuncta*	(MacGillivray, 1883)	PPH
Pl. 175, Fig. 7	*Microporella scandens*		*Calwellia?*		PPH
Pl. 175, Fig. 8	*Microporella ciliata* var. *spicata*				
Pl. 175, Fig. 9	*Microporella ciliata* var. *personata*				
Pl. 175, Fig. 10	*Microporella malusii* var. *personata*				
Pl. 175, Fig. 11	*Microporella malusii* var. *thyreophora*				
Pl. 175, Fig. 12	*Escharipora stellata*		*Triporula biarmata*	(Waters, 1882)	PPH
Pl. 176, Fig. 1	*Stomatopora geminata*		*Stomatopora geminata*	MacGillivray, 1887	
Pl. 176, Fig. 2	*Flosculipora pygmaea*		*Flosculipora pygmaea*	MacGillivray, 1887	PPH
Pl. 176, Fig. 3	*Lichenopora magnifica*				PPH
Pl. 176, Fig. 4	*Lichenopora bullata*		*Disporella bullata*	(MacGillivray, 1887)	PPH, Warrnambool, Portland
Pl. 177, Fig. 1,2	*Craspedozoum ligulatum*		*Menipea ligulata*	(MacGillivray, 1886)	PPH
Pl. 177, Fig. 3	*Craspedozoum spicatum*		*Menipea spicata*	(MacGillivray, 1886)	PPH
Pl. 177, Fig. 4,5	*Craspedozoum roboratum*		*Menipea roborata*	(Hincks, 1881)	PPH
Pl. 177, Fig. 6	*Menipea funiculata*		*Amastigia funiculata*	(MacGillivray, 1886)	PPH
Pl. 178, Fig. 1	*Aetea recta*		*Aetea sica*	(Couch, 1844)	PPH
Pl. 178, Fig. 2,3	*Scruparia chelata*		*Scruparia ambigua*	(d'Orbigny, 1847)	PPH
Pl. 178, Fig. 4,5	*Rhabdozoum wilsoni*		*Rhabdozoum wilsoni*	(Hincks, 1882)	PPH
Pl. 178, Fig. 6	*Farcimia appendiculata*		*Nellia appendiculata*	(Hincks, 1883)	PPH
Pl. 178, Fig. 7	*Catenicella ringens*		*Catenicella ringens*	Busk, 1852	PPH
Pl. 178, Fig. 8	*Dimetopia hirta*		*Dimetopia hirta*	MacGillivray, 1886	PPH
Pl. 185, Fig. 1	*Amathia bicornis*		*Amathia acervata*	Lamouroux, 1824	PPH

Plate	Name Used	Remarks	Current Name	Author	Locality
Pl. 185, Fig. 2	*Amathia spiralis*		*Amathia convoluta*	Lamarck, 1816	PPH
Pl. 185, Fig. 3	*Amathia tortuosa*		*Amathia tortuosa*	Tenison Woods, 1880	PPH, Wilsons Prom.
Pl. 185, Fig. 4	*Amathia inarmata*		*Amathia biseriata*	Krauss, 1837	PPH
Pl. 185, Fig. 5	*Amathia australis*		*Amathia woodsii*	(Goldstein, 1879)	PPH
Pl. 186, Fig. 1	*Schizoporella rostrata*		*Bitectipora rostrata*	(MacGillivray, 1887)	PPH
Pl. 186, Fig. 2	*Schizoporella woosteri*		*Stephanollona orbicularis*	(Hincks, 1881)	Queenscliff
Pl. 186, Fig. 3	*Schizoporella pulcherrima*				PPH
Pl. 186, Fig. 4	*Schizoporella latisinuata*				PPH
Pl. 186, Fig. 5	*Schizoporella biturrita*		*Calyptotheca variolosa*	(MacGillivray, 1869)	PPH
Pl. 186, Fig. 6	*Schizoporella pachnoides*		*Metroperiella montferrandi*	(Audouin, 1826)	PPH
Pl. 186, Fig. 7-9	*Schizoporella hyalina*				
Pl. 187, Fig. 1-2	*Membraniporella distans*		*Membraniporella distans*	MacGillivray, 1882	PPH, Warrnambool
Pl. 187, Fig. 3-4	*Cribrilina radiata*				PPH
Pl. 187, Fig. 5	*Cribrilina setirostris*		*Cribralaria setirostris*	(MacGillivray, 1883)	PPH
Pl. 187, Fig. 6	*Cribrilina monoceros*		*Arachnopusia unicornis*	(Hutton, 1873)	PPH, Warrnambool
Pl. 187, Fig. 7	*Cribrilina acanthoceros*		*Arachnopusia acanthoceros*	(MacGillivray, 1887)	PPH
Pl. 187, Fig. 8-9	*Hippothoa divaricata*		*Hippothoa divaricata*	Lamouroux, 1821	PPH, Hobsons Bay
Pl. 187, Fig. 10-13	*Hippothoa distans*		*Hippothoa distans*	(MacGillivray, 1869)	PPH, Hobsons Bay
Pl. 187, Fig. 14	*Electra amplectens*		*Heterooecium amplectens*	(Hincks, 1881)	PPH
Pl. 195, Fig. 1,2	*Stirparia glabra*		*Caulibugula glabra*	(Hincks, 1883)	Lorne
Pl. 195, Fig. 3	*Beania intermedia*		*Beania intermedia*	(Hincks, 1881)	PPH
Pl. 195, Fig. 4	*Beania conferta*		*Beania conferta*	MacGillivray, 1886	PPH, Portland
Pl. 195, Fig. 5	*Beania wilsoni*		*Beania wilsoni*	MacGillivray, 1885	PPH
Pl. 195, Fig. 6	*Verrucularia dichotoma*		*Elzerina blainvillii*	(Lamouroux, 1816)	PPH
Pl. 196, Fig. 1	*Thairopora armata*		*Thairopora armata*	(MacGillivray, 1869)	Queenscliff
Pl. 196, Fig. 2	*Thairopora mamillaris*		*Thairopora mamillaris*	(Lamouroux, 1816) ?	
Pl. 196, Fig. 3	*Thairopora jervoisii*		*Thairopora jervoisii*	(Hincks, 1880)	Sorrento
Pl. 196, Fig. 4-5	*Micropora coriacea*				
Pl. 196, Fig. 6	*Micropora coriacea* var. *angusta*		*Micropora angusta*	MacGillivray, 1887	
Pl. 196, Fig. 7-10	*Rhyncopora bispinosa*				PPH
Pl. 196, Fig. 11-14	*Rhyncopora longirostris*				PPH, Portland, Warrnambool

McCoy's Contribution to Graptolithology

Noel Schleiger[1]

Introduction

This study is confined to Frederick McCoy's publications on the description and occurrence in Victoria of graptolites, as inferred from his various reports in the *Prodromus of Palaeontology of Victoria* 1874-1881. The aim is to relate McCoy's descriptions and concepts to the present-day situation, especially with regard to the advances in graptolite taxonomy over the last 100 years.

In 1854 McCoy was appointed Professor of Natural Science in the University of Melbourne. In 1856 he was appointed Palaeontologist to the Geological Survey of Victoria, and later became Director of the National Museum of Victoria. Therefore, he held these three positions concurrently. Geologists working on the Survey collected specimens which were subsequently housed in the National Museum. McCoy supplied the age determinations most necessary for compiling the Geological Quarter Sheets, and described those fossils for taxonomic determination. McCoy provided this service efficiently until shortly before his death in 1899 (Darragh *et al.* 1976).

McCoy had previously worked with Adam Sedgwick on the graptolites in Scotland, Wales and Ireland, and was aware of collections from Sweden, Bohemia and Canada.

McCoy's work in the *Prodromus*

Brough Smyth was appointed Secretary for Mines in Victoria in 1860. He instituted several important geological publications, such as the Reports of Mining Surveyors and Registrars which recorded significant data on the Victorian Goldfields. He also supported Frederick McCoy's *Prodromus of the Palaeontology of Victoria,* which was issued in seven parts between 1874 and 1882.

The idea was to produce *Memoirs of the National Museum*, and *Prodromus* was the start. Darragh *et al.* (1976) rate this work as one of the finest Australian palaeontological publications. Of the eleven taxonomic fossil groups, graptolites ranked second in the number of species described by McCoy in the various decades of the *Prodromus* (1874-1881).

In Decade I in his discussion of the graptolites he regards these fossils as very important in the dating of the Lower Silurian (now Ordovician), especially the gold deposits of Victoria.

Table 1 shows the graptolites in Decades I, II and V, making 19 species in all which he described in the *Prodromus.*

Early discovery of graptolites in Victoria

Darragh *et al.* (1976) report that the first Silurian graptolites came from Keilor in May 1856, found by Selwyn and Aplin, whilst the first from the Ordovician were found by Thureau at Bendigo in 1857. J.H. Panton, Warden of the Bendigo Goldfield, gave McCoy graptolite specimens from Bird Reef, Bendigo in 1858. From these collections McCoy realised that graptolites were world-wide in their distribution and not just in the northern hemisphere in the Ordovician period. He was most impressed when he found that the very same graptolite species at Bendigo also occurred in the old goldmines at Gogofau in Wales (McCoy 1874).

Evolution of graptolite taxonomy

Uniserial forms

It is interesting to read McCoy's report of the first Lower Ordovician graptolites from Bendigo. It makes one appreciate how the taxonomy and terminology has changed and developed from these first descriptions.

In the *Prodromus* (McCoy 1874), the generic name *Graptolites* was applied to all those species having 'one row of cells' (known today as 'thecae'; Fig. 1) on each branch or stem (today referred to as the 'stipe'). If the polypidium – the whole body of the fossil (today known as the 'rhabdo-

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Table 1. Graptolites described by McCoy in the various decades of the *Prodromus of the Palaeontology of Victoria.*

Decade No.	Plate No.	Figure No.	Genus or Sub-genus	Species	Age Today
I	I	1-4	*Phyllograptus*	*folium* var. *typus*	Bendigonian
		5	*Diplograpsus*	*mucronatus*	Llandeilo
		6	*Diplograpsus*	*pristis*	Llandeilo
		7	*Diplograpsus*	*rectangularis*	Llandeilo
		8	*Diplograpsus (Climacograpsus)*	*bicornis*	Llandeilo
		9-14	*Graptolites (Didymograpsus)*	*fruticosus* (Hall)	Bendigonian
	II	1	*Graptolites (Didymograpsus)*	*quadribrachiatus* (Hall)	Bendigonian
		2,3,5	*Graptolites (Didymograpsus)*	*bryonoides*	Lower to Middle Ordovician
		4	*Graptolites (Didymograpsus)*	*octobrachiatus*	Castlemainian
		6	*Graptolites (Didymograpsus)*	*logani* (Hall) var. *australis* (McCoy)	Castlemainian
II	XX	1	*Graptolites (Didymograpsus)*	*extensus* (Hall)	Lower Ordovician
		3-5	*Graptolites (Didymograpsus)*	*caduceus* (Salter)	Castlemainian (Lower Ordovician)
		6	*Diplograpsus*	*palmeus* (Barrande)	Upper Ordovician
		2	*Cladograpsus*	*ramosus* (Hall)	Upper Ordovician
		7	*Cladograpsus*	*furcatus* (Hall)	Upper Ordovician
		9	*Graptolites (Didymograpsus)*	*gracilis*	Upper Ordovician
		10	*Retiolites*	*australis*	Wenlock (Silurian)
V	L	1-4	*Graptolites (Didymograpsus)*	*thureaui* (McCoy)	Bendigonian (Lower Ordovician)
		5	*Graptolites (Didymograpsus)*	*headi* (Hall)	Castlemainian (Lower Ordovician)

some') – had two simple stems (stipes) united by a slender non-celluliferous base (today, the 'sicula') the subgenus *Didymograpsus* (twin graptolites) was applied.

At this stage of the evolution of the taxonomy, all multi-branched forms were designated *Graptolites (Didymograpsus)* presumably because fragmentary stipes could not be distinguished from part of *Didymograpsus,* or the distal fragment of a many branched form. The species name could be applied to a multi-branched form when the complete specimen was available. In today's taxonomy that species name has often been retained, and this is the best clue to link the terminology of McCoy with that of today. Three examples of the multi-branched forms are shown in Fig. 2.

A feature of the evolution of the *Didymograpsus* subgenus throughout the Lower Ordovician period was to drop the number of stipe dichotomies (stipe orders) from six down to two. Thus, in Fig. 2, *Loganograptus,* with four dichotomies, reduces to three in *Dichograptus* and to two in *Tetragraptus.*

Biserial Forms

The name *Diplograpsus* was applied in the 19th century to those graptolites with 'two rows of cells or denticles'. Before coming to Victoria, McCoy had recorded biserial forms in Britain and Ireland (McCoy 1846; Sedgwick and McCoy 1855), based on Professor Hall's work in Canada, viz: *Diplograpsus foliaceus*

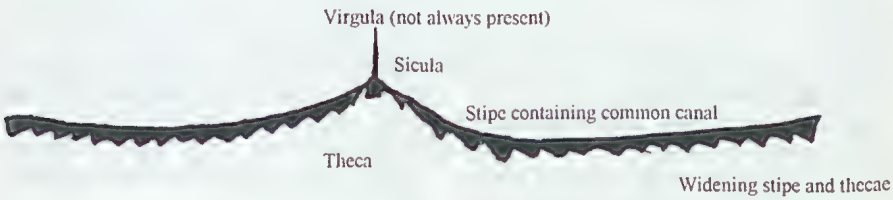

Fig. 1. Graptolite *Didymograpsus extensus* (Hall), today known as *Expansograptus balticus,* a lower Ordovician uniserial form.

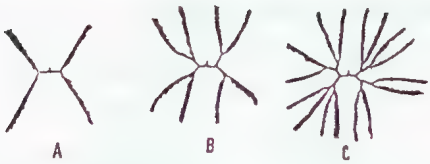

Fig. 2. Three multi-branched graptolites described by McCoy from the Bendigo Goldfields (modern taxonomy in brackets): a, *Graptolites (Didymograpsus) quadribrachiatus* (Hall) (*Tetagraptus quadribrachiatus*); b, *Graptolites (Didymograpsus) octobrachiatus* (Hall) (*Dichograptus octobrachiatus*); c, *Graptolites (Didymograpsus) logani* var. *australis* (*Loganograptus logani*).

(Murchison), *D. folium* (Hisunger), *D. mucronatus* (Hall), *D. pristis* (Hisinger sp.) var. B (Hall), *D. ramosus* (Hall), *D. rectangularis* (McCoy), and *D. ? sextans* (Hall).

McCoy realised that the distinction between *Didymograpsus* and *Diplograpsus* forms was important. However, at this stage it was not realised that the sequence of graptolite forms through the Ordovician succession went from uniserial to biserial and then back to the uniserial condition in the Upper Ordovician succession.

Thus in the bottom third of the Lower Silurian (Llandoverian), biserial forms became extinct and only uniserial forms, usually Monograptidae, existed until the extinction of the graptolites in the Emsian division of the Lower Devonian (Thomas 1960; Cas and VandenBerg 1988; VandenBerg 1988).

The problems with the subgeneric classification of graptolites into *Didymograpsus* were that *Didymograpsus* did not distinguish between the number of stipes in the rhabdosome; also *Didymograpsus* did not differentiate forms which were uniserial in the Lower Ordovician and Upper Ordovician through Silurian to Lower Devonian (Emsian) sequences.

Concepts inferred from McCoy's reports on graptolite taxa

Taxonomy of the graptolites

Features of McCoy's fossil reports were to designate the Class, Order and Family of the fossil under study, together with a brief resume of the taxonomy at that time. This was followed by a detailed description with salient measurements, then by discussion and localities of occurrence.

The well-known Bendigonian zone fossil of today, *Pendeograptus fruticosus*, was described by McCoy (1874) as *Graptolites (Didymograpsus) fruticosus* (Hall).

This was the first Victorian graptolite McCoy was to see when he arrived in Victoria (McCoy 1874). McCoy immediately recognised it as a new species. At that time he named it in his manuscript *Graptolites (Didymograpsus) pantoni* after J.A. Panton, then warden of the Bendigo goldfield. McCoy corresponded with Prof. Hall of Canada, who subsequently had discovered the same species there. Hall had sent McCoy a proof of his illustration of *Graptolites (Didymograpsus) fruticosus* before publication, so McCoy adopted Hall's name.

Of this taxon, McCoy remarked,

> the extraordinary symmetrical grace of the regular form in which this most beautiful species is developed, renders it very easy of recognition. Even fragments are clearly marked by the great size of the broad triangular denticles.

A feature of the gerontic forms of this graptolite is the broadening curving of the distal end of the stipes, with corresponding increase of thecal size (Fig. 3).

Were graptolites hydrozoans?

McCoy thought that the thin horny rhabdosome with either uniserial or biserial thecae and polyp cells, each having an internal transverse diaphragm at the base, were features agreeing with the Hydrozoan Sertulariadae. However, the graptolites were not rooted like *Sertularia* and there is no trace of ovarian vesicles. *Corymorpha*, another hydrozoan, on the other hand, agrees with the graptolites in having a free rhabdosome.

In Ireland, McCoy's friend, Patterson of Belfast, noted that a broken stem of the hydroid zoophyte of *Tubularia*, when immersed in water, 'kept coiling itself up then uncoiling, twisting and knotting itself,' which conveyed the notion that the stem is not only flexible, but truly and entirely under the control of the zoophyte (McCoy 1846).

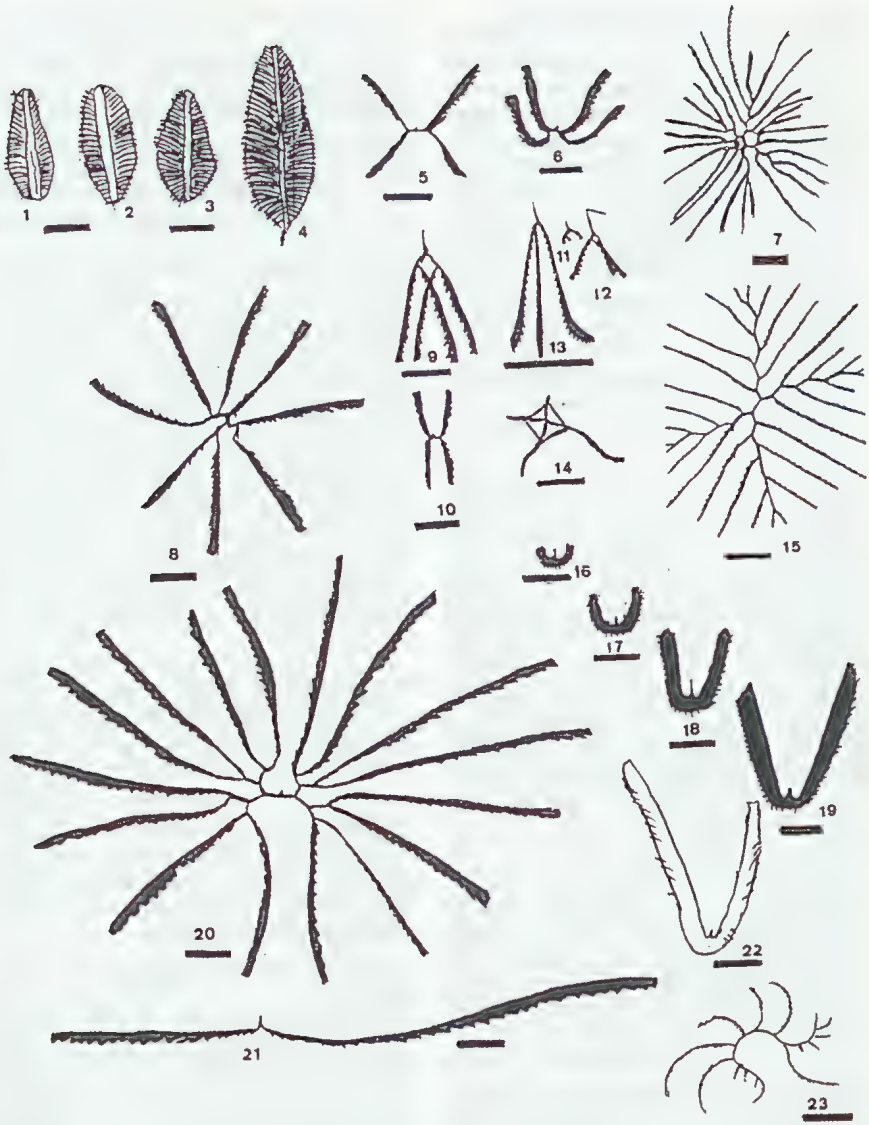

Fig. 3. Uniserial graptolites designated by McCoy mostly as the subgenus *Didymograpsus* (see Table 3). Scale Bars all represent 1 cm. 1-4, *Phyllograptus typus* showing variation in form. 5, *Tetragraptus quadribrachiatus*. 6, *Tetragraptus serra*. 7, *Goniograptus thureaui* var. *clonograptoides*. 8, *Dichograptus octobrachiatius*. 9, *Pendeograptus fruticosus* 4 Br. form. 10, *Tetragraptus approximatus* included as a zone fossil for Be-1 with *P. fruticosus* (4 Br.). 11, 12, 13, *Pendeograptus fruticosus* 3 Br. form, juvenile (11), young (12), old/mature specimens (13). 14, *Tetragraptus headi*. 15, *Goniograptus thureaui* var. *inequalis?* 16, 17, 18, 19, 22, *Isograptus caduceus* varieties: 16 var. *lunatus* (Ca-1), 17 var. *victoriae* (Ca-2), 18 var. *maximus* (Ca-3), 19 var. *maximo-divergens* (Ca-4), 22 var. *divergens* (Ca-3 - Ya-1). 20, *Loganograptus logani*. 21, *Expansograptus extensus*. 23, *Nemagraptus gracilis* (Gi-1).

The modern concept of graptolites

Debate has continued on the position of graptolites in the animal kingdom since McCoy's time. Ruedemann (1947) considered that graptolites were still allied closely to the Hydroidea, a view expressed first by Hall (1865) which no doubt influenced McCoy's views of graptolites at the time he described the Victorian graptolite fauna.

Kozlowski (1948) argued that on structural considerations graptolites were neither Coelenterates nor Bryozoans (Polyzoans). Their histology and method of budding indicates that they are most likely to be Pterobranchiata. Kozlowski (1948) has discovered a colonial form related to the living *Cephalodiscus*, the earliest Pterobranchiate.

Palmer and Rickards (1991) regard graptolites as colonial animals, like corals and most bryozoans, which they resemble. The individuals of the colony (zooids) were connected with living tissue, but the graptolite colony is usually much more geometric in its arrangement. Further, the skeletons of corals and bryozoans are largely calcareous, whilst those of graptolites are of tough, horny material called collagen. Collagen is a fibrous protein, generally preserved as black carbon, and is common today in the bones, skin and heart tissue of vertebrates.

As graptolites are extinct, the Graptoloidea ranging from Lower Ordovician to Lower Devonian, and the Dendroidea ranging from Middle Cambrian (550 Ma) to Upper Carboniferous (300 Ma), comparison with living creatures is very difficult. Today, the majority of graptolite workers regard them as hemichordates. Living hemichordates, such as *Cephalodiscus* and *Rhabdopleura,* have an external layer of soft, living tissue (known as extra-thecal tissue) connecting all the zooids. It is believed the Hemichordates linked the Invertebrates with the Vertebrates.

Observations by McCoy on some graptolite species

Lower Ordovician Uniserial Graptolites

Phyllograptus folium (Hisinger) var. *typus* (Hall)

McCoy was aware of the variation in size and form of this species. From studies of the Bohemian and Swedish species (*Didymograpsus (Phyllograptus) ovatus* (Barrande)) he predicted that they may only be varieties of *D. (P.) folium* of Hisinger. The Australian type in length and width was three or four times the size of the European varieties. The most distinctive character was the extraordinary width and thickness of the midrib or axis, which was about a quarter inch thick in the Bendigo examples. The thicker 'midrib' may be the result of two adjacent leaf-like stipes at right angles being flattened in one plane, or from one of the stipes being broken through. At least the thecae per inch or cm seemed to be constant in all species studied. McCoy remarked that this species varies from ovate to most commonly broad and semi-elliptical at the basal half, then narrowing with straighter sides towards the upper or distal end which was obtusely rounded. Other forms were the nearly regular ellipse, whilst still rarer forms had parallel sides and nearly equally rounded ends.

Hall (1865) applied the genus *Phyllograptus* to *Didymograpsus* (*Phyllograptus*) *folium* (Hisinger) from the Canadian Hudson River Formation. Hall referred an identical series of Phyllograptids which McCoy had described from Bendigo as *P. typus.* McCoy thus adopted the name *P. typus* for his large variety which was found at Lancefield, Newham, on the east bank of the Loddon, Jackson's Creek, Bullengarook and elsewhere.

Graptolites (Didymograpsus) caduceus (Salter)

McCoy described a variety of sizes of this scandent didymograptid, such as a small form and the large, broad, widely diverging forms. He believed the large forms were a distinct variety from the narrow subparallel forms, but there was a general gradation or series in size on the sample of specimens available. The common occurrence was in Castlemaine and district.

Thomas (1960) regards this species as synonymous with *Isograptus caduceus* (Salter) c.f. *I. gibberulus* and *Didymograptus gibberulus* with a list of 18 variants distinguished by later workers, especially Harris, T.S. Hall and Keble and Benson. So McCoy was correct in his

observation that there were varieties in morphology and size.

Today, the recognition of the four Castlemainian sub-zones of the Victorian Lower Ordovician depend on the presence of various subspecies of *Isograptus victoriae,* as shown by Cas and VandenBerg (1988), and by VandenBerg and Cooper (1992).

Graptolites (Didymograpsus) quadribrachiatus (Hall)

Ruedemann (1947) describes *Tetragraptus quadribrachiatus* (Hall) as consisting of first order stipes of 2.6 mm with two thecae on each side. Four second order stipes spread out obliquely; straight, slender and rigid, increasing very gradually from 0.6 mm wide, to a maximum width × length of 2.4 × 42 mm. Eight to nine thecae per cm inclined at about 35-40° and about four times longer than wide. Overlap is one half to one third of their length, then outer wall slightly curved. Apertural thecal margins are straight or slightly concave, and normal to the stipe axis.

The modern taxonomy is *Tetragraptus* (Salter 1863) *quadribrachiatus* (Hall). This graptolite has proved to be long-ranging, from the Bendigonian to the Darriwilian in Victoria.

Graptolites (Didymograpsus) logani (Hall)

The rhabdosome is made up of two first order branches about 2 mm long dividing into four short second order branches about 1.4 mm long. Two repeated dichotomies in equal short intervals produced 16 fourth order stipes. However, it is possible to find one or other of third order dichotomies suppressed, or a fifth order dichotomy to give anything from 13 to 25 stipes. Stipes of the last order can be up to 18 cm long. Thecae are 8-10 per cm and three times longer than wide with an overlap of one half inclined at 30°. A large central disc may be present in the larger specimens.

Today VandenBerg and Cooper (1992) refer to this species as *Loganograptus logani logani* (Hall). The species described by McCoy was referred to as *Loganograptus logani australis* (McCoy). VandenBerg and Cooper regard McCoy's description as synonymous with *Loganograptus logani logani* (Hall) and the variation from *L. l. australis* dubious.

Graptolites (Didymograpsus) octobrachiatus Hall

The rhabdosome is made up of stipes of three orders. The first order are about 2 mm long, dichotomously branching to four second order stipes 1.5 mm long. The eight branches can be up to 10 cm long and up to 3.6 mm wide. Thecae are 8-10 per cm and about four times longer than wide. Overlap is 2/3 with a 20° inclination, curving to an outer margin of 50-55° to the stipe axis. Apertural margins are at 105-110° angle with the stipe axis. A secondary disc may be present in mature rhabdosomes. The present day taxonomy is *Dichograptus octobrachiatus* (Hall).

Graptolites (Didymograpsus) thureaui (McCoy)

This was a new genus to Hall when in 1861 McCoy sent him a proof of his plate of graptolites from the *Prodromus of the Palaeontology of Victoria* (Ruedemann 1947). *Goniograptus* was later found in Quebec rocks by Ami (1889) and from the Deep Kill by Ruedemann (1902). Thomas (1960) indicates that the species now has two variants, *Goniograptus thureaui* (McCoy) var. *clonograptoides* Harris and Thomas, and *Goniograptus thureaui* (McCoy) var. *inequalis* Harris and Thomas, which is synonymous with *G. thureaui* var. *thureaui,* both of which are Bendigonian Sub-zone 1, but the latter extending into the Be-2 Sub-zone. VandenBerg and Cooper (1992) show the range of *G. thureaui thureaui* as spanning the Bendigonian zone from Be-1 to Be-4, but restrict *G. thureaui,* var. *clonograptoides* to Be-1 only.

Graptolites (Didymograpsus) headi (Hall) Ruedemann (1947)

This is a four-stiped rhabdosome, stipes in pairs joined by a short funicle at the base and united in a broad, thickened, quadrangular, nearly square disc with a slight extension along the stipes. Thecae are ten per cm; length four times the width. Distinguished from the similar *Tetragraptus quadribrachiatus* by the size of the stipes, *T. headi* (Hall) is confined to the Castlemainian sub-zone 4 and tends to be rare in occurrence.

Upper Ordovician Biserial Graptolites

Diplograpsus mucronatus

This species is easily recognized by the little mucronate film that terminates each denticle and which extends upwards, downwards and horizontally (Fig. 4). Hall describes this species also from the Hudson River Formation not far from the British Caradoc Shale. McCoy described it from Jackson's Creek, Parish of Bulla. Thomas (1960) lists this species and synonym under *Lasiograptus (Hallograptus) mucronatus* Hall as an Eastonian graptolite in Victoria (Caradoc in Britain). VandenBerg and Cooper (1992) list two taxa, *Hallograptus hirtus* var. *mucronatus* (Hall) and *Hallograptus bimucronatus* which ranges from Eastonian sub-zones 2 to 3. They regard that it is doubtful that *D. mucronatus* occurs in Australia.

Diplograpsus pristis (Hisinger).

Occurring with *D. mucronatus*, McCoy described *D. pristis* (Hisinger) with broad triangular thecae and slightly mucronate tips. The thecae were less oblique to the axis but more strongly and broadly toothed than in *D. mucronatus*.

Thomas (1960) more recently listed this species as *Diplograpsus (Orthograptus) pristis* Hisinger. This has turned out to be an Eastonian or Caradoc form in the Upper Ordovician succession. VandenBerg and Cooper (1992) do not list it anywhere in their evaluation of the Eastonian graptolite occurrences.

Diplograpsus rectangularis McCoy

Similar to *D. pristis* is *Climacograptus rectangularis*, but it has short square thecae, set normal to the axis of the rhabdosome. The denticles of the thecae approach those of *C. bicornis*, but the base is a point and not bicornate as in that species. VandenBerg and Cooper (1992) have reassigned this form to *Pseudoclimacograptus ridellensis* (Harris) from Thomas's (1960) determination of *Climacograptus ridellensis* (Harris). McCoy reported that this form was in association with *D. mucronatus* and *D. pristis*, in what is presently known as the Eastonian zone.

Diplograpsus (Climacograptus) bicornis (Hall)

The fourth *Diplograpsus* described by McCoy in Plate I of the *Prodromus* was the distinctive *D. (Climacograptus) bicornis* (Hall), with the thecae 'squarely notched out of the side margins' with a characteristic bicornate base. Cas and VandenBerg (1988) show this as *Climacograptus bicornis bicornis* and as being basal Gisbornian in the Upper Ordovician. They also show another subspecies, *C. bicornis tridentatus* in the Upper Gisbornian. So with the advance of the science since McCoy's description, this graptolite has proved to be very useful in the stratigraphical mapping of the lowest division (Gisbornian) of the Upper Ordovician in Victoria. Later workers have distinguished the following variants of this species: *C. bicornis inequispinosus* Thomas; *C. bicornis longispinus* T.S. Hall; *C. bicornis peltifer* Lapworth (syn. *C. bicornis bicornis*); and *C. bicornis tridentatus* Lapworth. Thus *C. bicornis* ranges throughout the Gisbornian zone with the variants indicating particular sub-zones.

Diplograpsus palmeus (Barr).

By comparing the specimens from the parish of Bulla with those from Bohemia in the National Museum, McCoy believed this pear-shaped rhabdosome with cordiform outline which had a smooth dilatation at the distal end was an ovarian vesicle. What McCoy described later proved to be typical of the genus *Petalograptus* and this species is listed by Thomas (1960) as *Petalograptus palmeus* Hall.

Cladograpsus ramosus (Hall).

McCoy (1875) felt that the name *Cladograpsus* rather than *Dicranograptus* should apply to his specimens from the Parish of Bulla. However, in later documentation such as Thomas (1960) this graptolite is catalogued as *Dicranograptus ramosus* Hall with the variants *longicaulis* Elles and Wood, *semi-spinifer* T.S. Hall and var. *spinifer* Lapworth (syn. *semi-spinifer*) figured in Plates VII and IX of the *Prodromus*. Cas and VandenBerg (1988) figure *Dicranograptus ramosus semi-spinifer*. Thus *Dicranograptus* as the genus took precedence over *Cladograpsus*. VandenBerg and Cooper (1992) regard *Dicranograptus ramosus ramosus* Hall as equivalent to *Dicranograptus ramosus spinifer* Elles and Wood. Its range in the Gisbornian zone is Gi-1 to Gi-2.

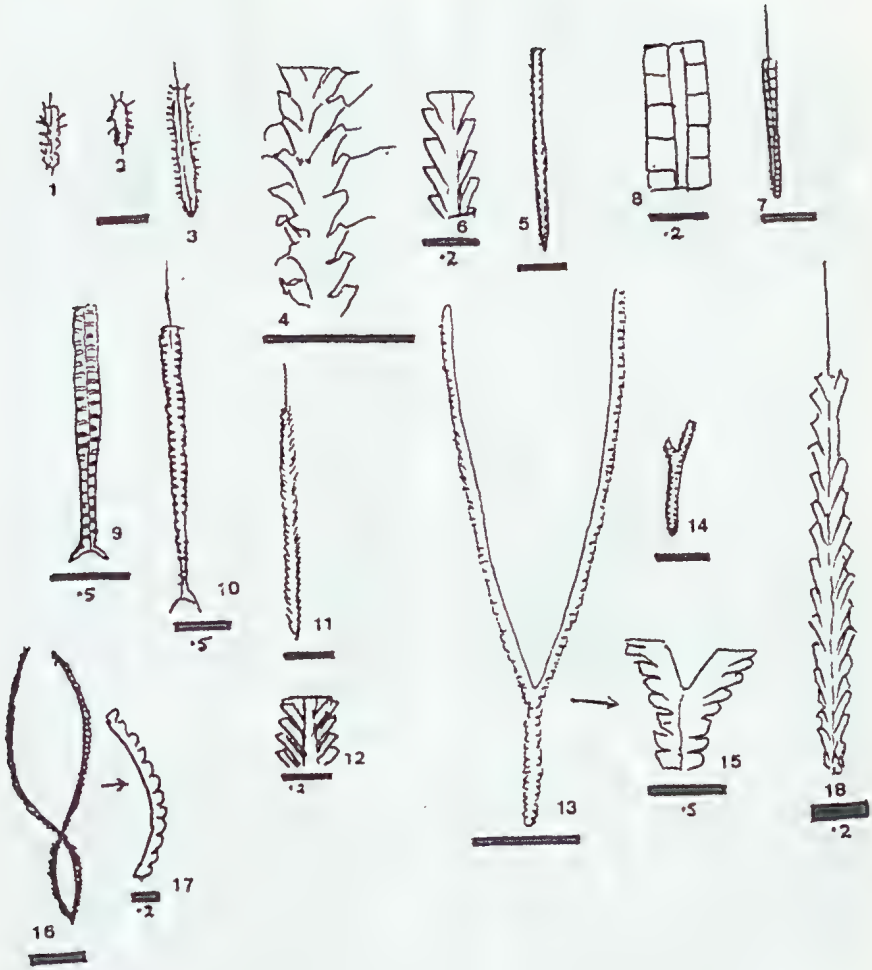

Fig. 4. Biserial graptolites designated by McCoy mostly as the subgenus *Diplograpsus* (see Table 3). Scale Bars represent 1 cm, except where indicated otherwise. 1, 2, 3, 4, *Lasiograptus (Hallograptus) mucronatus;* young (1), juvenile (2), mature specimen (3), enlargement of distal part of rhabdosome to show mucronate tips of thecae (4). 5, 6, *Diplograpsus (Orthograptus) pristis*; mature specimen (5), enlargement to show distal thecal characteristics (6). 7, 8, *Climacograptus rectangularis,* now *Pseudoclimacograptus riddellensis* Harris; mature specimen (7), distal enlargement to show rectangular thecae (8). 9, 10, *Climacograptus bicornis bicornis*; enlargement to show thecae (9), mature specimen (10). Note bicornate property of proximal end. 11, 12, *Petalograptus palmeus*; mature specimen (11), distal enlargement to show free thecae (12). 13, 14 *Dicranograptus ramosus* var. *spinifer*; enlargement to show change from biserial to uniserial thecae (15). 16, 17, *Dicranograptus furcatus*; enlargement to show uniserial stipe and thecae (17). 18 *Stomatograptus australis*, enlarged to show thecal details.

Table 2. Summary of changes in graptolite taxonomy of McCoy's 19 graptolite species.

No.	McCoy's Classification	Modern Classification	Value in Stratigraphy	Age Range in Victoria
1	*Phyllograptus folium* (His.) var. *typus* (Hall)	*Phyllograptus typus* (J. Hall)	Indicates Zone 4 with *Pendeograptus fruticosus* (3 Br)	Bendigonian Sub-zone 4 (Be-4)
2	*Diplograpsus mucronatus*	*Hallograptus hirtus* *Hallograptus bimucronatus*	Caradocian in Britain	Ea-2 - Ea-3 Eastonian Sub-zones
3	*Diplograpsus pristis*	*Diplograpsus (Orthograptus) pristis*	Caradocian in Britain	Eastonian Zone
4	*Diplograpsus rectangularis* (McCoy)	*Pseudoclimacograptus riddellinsis* (Harris)	Caradocian in Britain	Darriwilian Sub-zone 4 (Da-4) to Gisbornian Sub-zone 1(Gi-1)
5	*Diplograpsus (Climacograpsus) bicornis* Hall	*Climacograptus bicornis bicornis* (Hall)	Gisbornian, lowest Sub-zone in the Upper Ordovician succession	Gi-1 indicator with *Nemagraptus gracilis*
6	*Graptolites (Didymograpsus) fruticosus* (Hall)	*Pendeograptus fruticosus* (Hall)	2Br, 3Br & 4Br forms define the Sub-zones of the Bendigonian zone	Be-1 to Be-4 Sub-zones. Zone fossils
7	*Graptolites (Didymograpsus) quadribrachiatus* (Hall)	*Tetragraptus quadribrachiatus* (Hall)	Ranges from base of the Bendigonian to top of the Castlemainian zones	Be-1 to Be-4, Ch-1 to Ch-3, Ca-1 to Ca-4 Sub-zones. Long-ranging species
8	*Graptolites (Didymograpsus) bryonoides* (Hall)	*Tetragraptus bryonoides* (Hall) = *T. serra* Elles and Wood	Arenigian in Britain Bendigonian (Be), Chewtonian (Ch), Castlemainian (Ca), Yapeenian (Ya), Darriwilian (Da)	Be-3 to Da-3 Sub-zones. Long-ranging species
9	*Graptolites (Didymograpsus) octobrachiatus* Hall	*Dichograptus octobrachiatus* (Hall)	Bendigonian to Darriwilian zones	Long-ranging Be-1 to Da-2 Sub-zones
10	*Graptolites (Didymograpsus) logani* var. *australis* (McCoy)	*Loganograptus logani logani* (Hall)	*L. logani* Be-1 to Da-3	*L. logani logani* to Ca-3 Zone
11	*Graptolites (Didymograpsus) extensus* (Hall)	*Expansograptus extensus*	Lower Arenigian from Upper Tremadocian in Britain Lancefieldian, Bendigonian to Chewtonian in Victoria	La-3 to Ch-2 Sub-zones
12	*Graptolites (Didymograpsus) caduceus* (Salter)	*Isograptus victoriae lunatus*, *I. victoriae victoriae*, *I. victoriae maximus*, *I. victoriae maximo-divergens* *I. victoriae divergens* Harris	All variants used to Sub-zone the Castlemainian Zone. *I. v. divergens* indicates Ya-1	Ca-1 to Ca-4 on *I. v. l.* (Ca-1), *I .v. v.* (Ca-2), *I. v. m.* (Ca-3), *I. v. m.d.* (Ca-4)
13	*Diplograpsus palmeus* (Barrande)	*Petalograptus palmeus* Hall	Lower Llandovery in Wales	Keilorian (Llandovery) (Lower Silurian)
14	*Cladograpsus* (Geinitz) *ramosus* (Hall)	*Dicranograptus ramosus ramosus* (Hall) = *D. ramosus spinifer* Elles and Wood	Gisbornian Zone, Upper Ordovician	Gi-1 to Gi-2 Sub-zones
15	*Cladograpsus* (Geinitz) *furcatus* (Hall)	*Dicranograptus furcatus* (Hall) = *D. kirki*, = *D. f. minimus* (Lapworth)	Gisbornian Zone	Rare in Gisbornian Zone. Is doubtful
16	*Graptolites (Didymograpsus) gracilis* Hall	*Nemograptus gracilis* (Hall)	Marks the base of the Upper Ordovician in Victoria	Gi-1 Sub-zone with *Climacograptus bicornis bicornis*
17	*Retiolites australis* (McCoy)	*Stomatograptus australis* (McCoy)	Late Llandoverian	Springfield Formation in Central Victoria
18	*Graptolites (Didymograpsus) thureaui* (McCoy)	*Goniograptus thureaui thureaui* (McCoy) *Goniograptus thureaui clonograptoides* (Harris and Thomas)	Lower Bendigonian Zone Lower Bendigonian Zone	Be-1 to Be-4 Sub-zones Be-1 indicator
19	*Graptolites (Didymograpsus) headi* Hall	*Tetragraptus headi* (Hall)	Upper Castlemainian Zone	Ca-4 indicator but rare

Cladograpsus furcatus Hall

This species, described by McCoy (1875) as rare in the parish of Bulla, is documented by Thomas (1960) as *Dicranograptus furcatus* Hall. Later workers have shown this form to range from Gisbornian to mid-Eastonian. VandenBerg and Cooper (1992) state that numerous Australian records have listed this species, but there are no descriptions, which makes its presence uncertain.

Dicranograptus furcatus minimus Lapworth is equal to *Dicranograptus kirki*, so the presence of *D. furcatus* in Australasia is doubtful.

Graptolites (Didymograpsus) gracilis Hall

McCoy remarked on the smallness and inconspicuous nature of the thecae, which looked like root hairs instead of stipes, and that only the common canal running along the back of the thecae could be seen. However, there was a slight roughness indicating the presence of thecae as in New York specimens. He likened the specimens to *Rastrites*, except that the thecae were not tubular. McCoy was doubtful about this specimen being assigned to *Didymograpsus*, remarking that the unusual growth form could warrant another subgenus for its classification.

McCoy's suspicion was well founded as Thomas (1960) gives *Nemagraptus gracilis* as a separate genus and species. Cas and VandenBerg (1988) demonstrate that this graptolite is the zone fossil for the base of the Gisbornian (Gi-1) and with *Climacograptus bicornis* confirms the stratigraphical mapping of this zone.

This species marks the base of the Upper Ordovician succession in Victoria, and is also the zone fossil for the base of the Gisbornian Zone Gi-1.

Silurian Biserial Graptolites

Retiolites australis (McCoy)

McCoy reports that this specimen was found in a mudstone of Wenlock age in the United Kingdom. The Victorian occurrence is to the north-west of Keilor. *Retiolites* occurs at the base of the Upper Silurian in Bohemia. *Retiolites geinitzianus* (Barrande) was reported by VandenBerg (1988) to be associated with this species. It is listed by him in the Springfield Formation and indicates a Late Llandovery age. *R. australis* is very much smaller with nearly double the number of thecae per cm. Today *R. australis* is regarded as Late Llandovery in age.

Thomas (1960) indicates that *Retiolites australis* (McCoy) is a synonym of *Stomato-graptus australis* (McCoy).

Stratigraphic value in Victoria

Table 2 shows how the taxonomy of the 19 graptolite species, which McCoy described in the *Prodromous*, has evolved to the present day. It also shows the value of these species in Victorian stratigraphy.

Four of these species are rare and seem to have been lost in the evolving literature, viz *Dicranograptus furcatus, Tetragraptus headi, Climacograptus rectangularis (C. riddellensis harris)* and *Petalograptus palmeus*. Of the remainder, long-ranging species are four in number - *Tetragraptus quadribrachiatus, T. bryonoides, Dichograptus octobrachiatus* and *Expansograptus extensus*. This leaves eleven species which are restricted to subzones or are actual zone fossils (Table 3).

Table 3. Stratigraphic value of graptolites in McCoy's *Prodromus*.

Species	Sub-zone/Zone
Pendeograptus fruticosus (4 Br.) and *Tetragraptus approximatus*	Be 1
Pendeograptus fruticosus (4 Br. alone)	Be 2
Pendeograptus fruticosus (3 and 4 Br.)	Be 3
Pendeograptus fruticosus (3 Br. alone)	Be 4
Phyllograptus typus	Be 4
Isograptus victoriae var. *lunatus*	Ca 1
Isograptus victoriae var. *victoriae*	Ca 2
Isograptus victoriae var. *maximus*	Ca 3
Isograptus victoriae var. *maximo-divergens*	Ca 4
Climacograptus bicornis with *Nemagraptus gracilis*	Gi 1
Diplograpsus (Orthograptus) pristis and *Lasiograptus (Hallograptus) mucronatus*	Eastonian Zone
Stomatograptus australis and *Petalograptus palmeus*	Early Silurian (Keilorian)

Thus McCoy brought to the attention of graptolithologists eleven of the 19 species which needed further investigation for possible significance in Ordovician and Early Silurian stratigraphical mapping, not only in Victoria but world-wide.

Conclusion

The Australian Ordovician has now been divided into Upper and Lower divisions. The boundary between the two is at the base of the *Nemagraptus gracilis* zone of Cas and VandenBerg (1988).

Previously Harris and Thomas (1938) had proposed a three-part division with the Middle Ordovician (formerly the Darriwilian) between the Yapeenian Zone and the Gisbornian Zone. However, Cas and VandenBerg argue that this Middle Ordovician differs in concept from any other region. Furthermore, it represents only a relatively short time interval (VandenBerg and Cooper 1992). The present subdivision of the Ordovician in Victoria is consistent with the 1986 resolution, where the Cambrian-Ordovician boundary is below the *Dictyonema flabelliforme* band at Lancefield and the Ordovician-Silurian boundary is with the first appearance of *Parakidograptus acuminatus* at Darraweit Guim.

Such mapping detail has been the outcome of later workers capitalizing on McCoy's first descriptions of the 19 graptolite species discussed in this paper. As a result of this work, Victorian Ordovician graptolite sequences have been shown to be as complete as any in the world.

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'THE LATE PROFESSOR SIR F. M'COY, F.R.S., &C. - An appreciative memoir of the late professor appears in the *Geological Magazine* for June, 1899. After giving the general details of his life, an outline of which has already been published in these pages, a list is given of his smaller contributions to natural science. These number sixty-nine, extending from 1838 to 1876, with a final communication in 1881. They cover a vast range of subjects, and the greater number were published in the *Annals of Natural History Magazine*.'

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McCoy's Mammals

John Seebeck[1] and Robert M. Warneke[2]

Introduction

Although Frederick McCoy was principally a geologist and palaeontologist (Pescott 1954; Darrragh 1992), he was a true generalist, interested in and knowledgeable about a wide range of both invertebrate and vertebrate fauna, modern and fossil. As Professor of Natural Science at The University of Melbourne and Director of the embryonic National Museum of Victoria (now Museum Victoria) he recognised the necessity for such institutions to be able to demonstrate the diversity of life-forms to the community and was therefore at great pains to develop both teaching and exhibition collections. For whatever reasons – lack of time, lack of collecting opportunities or perhaps because the field had been so well covered by his contemporary and friend John Gould (whose singular publication *The Mammals of Australia* (Gould 1845-1863) was completed during McCoy's time as Professor) – McCoy did not specifically pursue the study of the contemporary mammals of Victoria. In an essay on the natural history of Victoria, written to accompany the catalogue of the 1861 Victorian Exhibition, McCoy observed that 'the Recent mammalia ... are so fully known from the admirable works [of Gould] that I shall not allude at all to them ...' (McCoy 1861: 170). However, when the opportunity arose for him to investigate something new, he did so with appropriate professional skill, and he investigated and described a number of mammal species, both contemporary and fossil. In this contribution we will examine these in their several categories.

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Descriptions of new, contemporary mammals

McCoy described and named two modern terrestrial mammal species, *Halmaturus wilcoxi* in 1866 (McCoy 1866), and *Gymnobelideus leadbeateri* in 1867 (McCoy 1867a). *Halmaturus wilcoxi* was described from two specimens collected by J.F. Wilcox at Richmond River, New South Wales. Iredale and Troughton (1934) placed the species in *Thylogale stigmatica*, subspecies *wilcoxi* Red-legged Pademelon. Dixon (1970) confirmed this nomenclature and noted that the type specimens, a female and a male, are held by Museum Victoria. According to Strahan (1995) the subspecies still stands.

Gymnobelideus leadbeateri Leadbeater's Possum was described from two specimens collected from the Bass River, and named after the skilled taxidermist at the National Museum, John Leadbeater. The original description, in the *Annals and Magazine of Natural History,* was illustrated with an uncoloured lithograph of a mounted specimen, fore- and hind-feet and teeth. The drawing was relatively crude and simplistic, but clearly recognisable (Fig. 1). The description, accompanied by a redrawn, coloured plate showing the animal, fore- and hind-feet and the skull and teeth, was re-published as Plate 91, in Decade X of the *Prodromus of the Zoology of Victoria* (McCoy 1878-1885). The genus and species still stand and Leadbeater's Possum is now one of Victoria's two State faunal emblems (the other being the Helmeted Honeyeater).

A third species of modern mammal was described in 1867, *Physalus grayi*, a 'new species of the genus *Physalus*, or "Finner"', from a specimen that washed up on the coast at Jan Juc in August 1866 (McCoy 1867b). Although this 'species' was subsequently synonymised within *Balaenoptera physalus* Fin Whale by Iredale and Troughton (1934), their deter-

Fig. 1. First illustration of Leadbeater's Possum *Gymnobelideus leadbeateri* McCoy. Lithograph by J. Basire. Published in *Annals and Magazine of Natural History, Series 3,* 1867, **20**, Plate 5, 287-88.

mination was in error, and Brazenor (1950) and later Wakefield (1967) recognised that the specimen was in fact *Balaenoptera musculus*, the Blue Whale. The full skeleton was articulated and displayed at The University of Melbourne until 1899, when it was apparently dismantled and disposed of rather than being reconstructed at the new Museum. A photograph of the skeleton, incorrectly captioned Black Right-Whale (Southern Right Whale, *Eubalaena australis*) is opposite p. 66 in Pescott (1954). All that remains are the right tympanic bulla and four baleen plates (Dixon and Frigo 1994).

Comments on, and descriptions of, contemporary mammals

McCoy was concerned with ensuring that the National Museum established its role as one of the essential cultural institutions of the increasingly sophisticated society that Melbourne was becoming. One way to demonstrate its value was by publishing scholarly and readily accessible accounts of the natural history of the colony, as had been already done for the geology and palaeontology. The publication of the *Prodromus of the Zoology of Victoria* (McCoy 1878-1885) was to be the precursor to a more detailed and comprehensive documentation of the natural history of Victoria. The *Prodromus* included descriptions and figures of three contemporary mammal species apart from *Gymnobelideus* – all are marine mammals, and one of them was featured twice. The species were the Sea Leopard (Leopard Seal), *Stenorhynchus* (= *Hydrurga*) *leptonyx* Plate 21, Decade III; Yellow-sided (= Common) Dolphin, *Delphinus novae zealandiae* (= *delphis*) Plate 22, Decade III; and Australian Sea-bear or Fur-seal (Australian Fur-seal), *Euotaria cinerea* (= *Arctocephalus pusillus*) Plate 31, Decade IV and Plate 71, Decade VIII.

Leopard Seals are not infrequent visitors to the Victorian coastline. The specimen illustrated was drawn from life by Ludwig Becker, the artist who died on the Burke and Wills expedition, and it became one of several specimens in the Museum collection. Interestingly, Gould himself figured this species, one of only two marine mammals that he included in *The Mammals of Australia* (the other being the Australian Sea Lion, *Neophoca cinerea*). Despite their vernacular name, Common Dolphins are not now at all common in Port Phillip Bay. The most abundant dolphin in the bay is the Bottlenose Dolphin *Tursiops truncatus* – McCoy (1878-1885: 10) noted that sailors called the dolphin the 'Bottle-nose'. The Australian Fur-seal rookery at Seal Rocks was visited by McCoy, where he collected an adult male and female, and a young one. The account accompanying Plate 71 provides a very detailed picture of the colony that today remains a major stronghold for the species.

In his 1861 essay, McCoy offered comment about the mainland existence of the Spot-tailed Quoll *Dasyurus maculatus*, which had hitherto been understood to be restricted to Tasmania. Several specimens had reached the Museum from the forests close to Melbourne. He also announced his recognition that the Dingo was indigenous, an issue that had been in debate at the time (McCoy 1861). In addition, he discussed the mammal fossil record in Victoria – but more of that later.

Five years later, Victoria hosted the Intercolonial Exhibition, and McCoy wrote another essay, titled *On the Recent Zoology and Palaeontology of Victoria*. By way of introduction, he explained that he would only refer 'to those species of animals affording economically useful materials, or of some special present interest in relation to unsettled scientific questions' (McCoy 1867b: 309); thus his comments did not set out to include observations on all the mammals known for the State. Indeed, he began by stating that 'very few of the Victorian quadrupeds are economically useful', and most of the notes were concerned with the value of the skin (as leather or fur) or the animal as food. It was an important part of colonial life to make use of the available natural resources, and McCoy may well have seen it as part of his educational role to give such advice as he could to the man in the street – and, hopefully, to the man in the bush as well. Marine mammals such as stranded large whales could and did provide oil and whalebone, both of which were extracted and sold.

Despite this somewhat narrow consideration of the State's mammal fauna, McCoy

Table 1. Mammals listed in McCoy's essay for the Intercolonial Exhibition, 1866-67.

Species, as reported in McCoy	McCoy's vernacular names	Present scientific name	Present vernacular
Dasyurus viverrinus	Native Cat	*Dasyurus viverrinus*	Eastern Quoll
Perameles obesula	Bandicoot	*Isoodon obesulus*	Southern Brown Bandicoot
Perameles fasciata	Bandicoot	*Perameles gunnii*	Eastern Barred Bandicoot
Phascolomys	Wombat	*Vombatus ursinus*	Common Wombat
Phalangista vulpina	Opossum	*Trichosurus vulpecula*	Common Brushtail Possum
Phalangista Viverrina var Victoriae	Ring-tail Opossum	*Pseudocheirus peregrinus*	Common Ringtail Possum
Hypsiprymnus	Kangaroo Rat	*Potorous tridactylus*	Long-nosed Potoroo
Lagorchestes	Hare-Kangaroo	*Lagorchestes leporides*	Eastern Hare-wallaby
Macropus fuliginosus	Sooty Kangaroo	*Macropus fuliginosus*	Western Grey Kangaroo
Macropus major	Old Man, Boomer Kangaroo	*Macropus giganteus*	Eastern Grey Kangaroo
Macropus ocydromus		*Macropus fuliginosus*	Western Grey Kangaroo
Halmaturus bennetti		*Macropus rufogriseus*	Red-necked Wallaby
Osphranter rufus	Red Kangaroo	*Macropus rufus*	Red Kangaroo
Halmaturus Brachyurus		*Thylogale billardierii*	Tasmanian Pademelon
Halmaturus uallabatus	Wallabi	*Wallabia bicolor*	Black Wallaby
Molossus australis		*Tadarida australis*	White-striped Freetail Bat
	Native Dog or Dingo	*Canis lupus dingo*	Dingo
*Arctocephalus lobatus**	Eared Seal	*Arctocephalus pusillus*	Australian Fur-seal
Stenorhynchus leptonyx	Sea Leopard	*Hydrurga leptonyx*	Leopard Seal
Physalus Grayi	Finner	*Balaenoptera musculus*	Blue Whale

* In the later *Prodromus of Zoology* (1878-1885), McCoy referred to this species as *Euotaria cinerea*, a combination apparently derived from J.E.Gray's 1866a, 1866b and 1871 reviews of fur seal and sea lion taxonomy. However, as Gray (1866b, 1871) erected *Euotaria* as a sub-genus of *Arctocephalus* including [South] American species, and *Gypsophoca* for Australian species, McCoy seems to have erred.

did list some of the species found in Victoria. It is a pity that he did not choose to provide a list of all the mammals known, as he did for the birds. Table 1 lists the species reported. Of interest are comments about the biogeography of the large kangaroos. McCoy believed that there were four species present and commented on the differences in appearance and distribution. Two species that he reported are now recognised to be conspecific – *Macropus fuliginosus* and *M. ocydromus* – but the taxonomy of the grey kangaroos was not sorted out until the 1970s (Kirsch and Poole 1972). McCoy was not just a narrowly focussed academic. He was very much alert to the ecological consequences of fencing pastoral land, which had resulted in a large increase in numbers of kangaroos, often necessitating the killing of 'hundreds ... on the squatters runs merely to save the grass for the sheep' (McCoy 1867b: 309). The increase in kangaroo numbers was also attributed to the extensive poisoning of Dingoes. Somewhat surprisingly, McCoy made errors of identification of the wallabies found in Victoria and Bass Strait, believing that the Black Wallaby (now *Wallabia bicolor*) was present on Bass Strait islands as well as in southern Victoria, and attributing the name of the Quokka *Setonyx brachyurus* of Western Australia to the Tasmanian Pademelon *Thylogale billardierii* which, in his time, was still present in coastal eastern Victoria. McCoy's confusion was possibly a reflection of the very limited reference material available to him in Australia and his unavoidable reliance on taxonomic reviews published in Europe, where most of the significant collections of birds and mammals were held. Many years were to pass before adequate geographically representative reference material was available in Australia for such comparative zoology.

Furs from possums and 'native cats' (*Dasyurus viverrinus*, Eastern Quoll and possibly also Spot-tailed Quoll) were also seen as desirable products, and McCoy urged the promotion of them into the

Table 2. Fossil mammals named by McCoy, with their present-day taxonomic standing. Date: Date of description.

Species, as named by McCoy	Date	Modern status of nomenclature	Authority
Dasyurus affinis	1865	*Dasyurus maculatus*	Mahoney 1964
Thylacoleo oweni	1876	*Thylacoleo carnifex*	Archer and Dawson 1982
Phascolomys pliocenus	1866	*Vombatus ursinus*	Wilkinson 1978
Diprotodon annextans	1861	Uncertain – possibly *D. australis*	Archer *et al.* 1984
Diprotodon longiceps	1865	Uncertain – was to replace *annextans*, and therefore possibly *D. australis*	Archer *et al.* 1984
Bettongia cuniculoides	1868	Uncertain – but most probably *B. gaimardi*, given the locality (Loddon River)	This paper; Archer *et al.* 1984 considered that the 'distinction of this taxon is unclear'
Hypsiprymnus trisulcatus	1865	*Potorous tridactylus*	Mahoney 1964
Arctocephalus williamsi	1866	*Neophoca cinerea*	Fordyce and Flannery 1983
Cetotolites baileyi	1879	*Nomen nudum**	Fordyce 1984
Cetotolites leggei	1879	*Nomen nudum*	Fordyce 1984
Cetotolites pricei	1879	*Nomen dubium***	Fordyce 1984
Cetotolites nelsoni	1879	*Nomen dubium*	Fordyce 1984
Cetotolites nelsoni var *rugosa*	1879	Ditto	Fordyce 1984
Parasqualodon wilkinsoni	1866	Possibly conspecific with *Prosqualodon davidis*	Fordyce 1984
Ziphius (Dolichodon) geelongensis	1882	*Nomen dubium*	Fordyce 1984
Physetodon baileyi	1879	Genus and species still stand, but possibly *nomen dubium*	Fordyce 1984

* *Nomen nudum*: A name that fails to conform to certain Articles in the International Code of Zoological Nomenclature (1985). It is not an available name and therefore the same name may be made available later, from which time the authority would date.
** *Nomen dubium*: A name of unknown or doubtful application.

European fur trade. 'So abundant and easily obtained are these skins ...' (McCoy 1867b: 309). Would that it were still so! The fur from the Fur Seal was reckoned to be 'of good quality when properly dressed' (McCoy 1867b: 309). However, these seals had been heavily exploited for many decades prior to McCoy's comments, and while there remained a sporadic and low-level trade in seal skins, the industry had effectively finished many years prior, so that despite the quality of the skins, there was not much profit to be made from the species by McCoy's time.

Descriptions of mammal fossils

McCoy's palaeontogical expertise was at the forefront in most of his mammalian investigations. Between 1861 and 1882 he described 16 taxa of fossil mammals (Archer *et al.* 1984; McCoy 1874-1882; Table 2). Nine of these descriptions appeared in the *Prodromus of Palaeontology*, 1874-1882.

He described *Diprotodon annextans* in 1861 and *D. longiceps* in 1865 (Archer *et al.* 1984 considered that this was a replacement name for *D. annextans*). He examined a collection of fossil bones found by A.R.C. Selwyn in a cave at Gisborne during the early 1860s, commenting on the species present in his 1861 essay. In a note that was present on some printings of a Geological Survey of Victoria map (GSV Quarter Sheet 7 NW, 1865), McCoy (1865) listed the following species of mammals as being present (we have reproduced the names as given): *Canis Dingo*; new Genus of Carnivorous animal; *Diabolus (Sarcophilus) Ursinus*; *Dasyurus viverrinus*; *Dasyurus affinis*; *Phalangista vulpina*; *Phalangista* New Species; *Perameles obesula*; *Hypsiprymnus trisulcatus*; *Macropus* nearly allied to *M. ualabatus*. He thus described two new species of marsupial – *Dasyurus affinis*, a 'new species nearly as large as *D. maculatus* but differing in proportions', and *Hypsi-*

prymnus trisulcatus, a new species a little smaller than the living *H. minor* and having only 3 sulci [grooves] on the large premolar in the lower jaw.

Mahoney (1964) reviewed the identities of the two new species and concluded that *Dasyurus affinis* was in fact *D. maculatus*, measurements and morphology of the syntypes falling within the normal range of that species. Gill (1953b) figured the syntypes, which appear to be typical *D. maculatus*. *Hypsiprymnus trisulcatus* was, similarly, relegated to a junior synonym of *Potorous tridactylus* by Mahoney, who pointed out that variation in the number of sulci was apparent within that species and thus was not a discriminating character. Mahoney considered that the fauna described in McCoy's note was representative of the modern fauna of the area. That is true, with the exception of *Sarcophilus*. Several records of that species in cave deposits in Victoria have been reported (Mahoney 1912; Gill 1953a, c) and it is likely that it was present on the mainland until fairly recently (in geological terms).

Mahoney (1964) was unable to identify McCoy's 'new Species of Carnivorous animal', noting that one possibility was *Hydromys chrysogaster* Water Rat. McCoy himself (1861) mentioned that *Hydromys* was present in the 'Mount Macedon caverns' (= Gisborne) deposits, but made no further reference to the species. *Hydromys* seems unlikely. Mahoney quotes Selwyn's description, which likens the skull to that of 'a domestic cat, but not more than half the size'; perhaps a kitten? The conundrum will remain unless the specimen is found.

McCoy was enthusiastic about fossil marine mammals and described nine species – one otariid seal, the remainder cetaceans. Fordyce (1984, 1991) has assessed these species and concluded that most are invalid. Further review may reveal that those names still standing are indeed synonyms.

It is a somewhat sad reflection of McCoy's diligent and knowledgeable descriptive zoology, then, that only one species of mammal, modern or fossil, has truly stood the test of time and review. It is, however, a pleasing legacy that that species should be Leadbeater's Possum, Victoria's only endemic mammal and one of its State Faunal Emblems.

Acknowledgements

We wish to thank Tom Darragh, Museum Victoria, for helpful discussions about Frederick McCoy and for the provision of copies of difficult-to-obtain references, and Carol Harris, Arthur Rylah Institute Librarian, for facilitating copies of other essential references. The State Library of Victoria provided a copy of McCoy's illustration of Leadbeater's Possum, which forms Fig. 1.

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Comments on the Ostracod Genus *Bairdia* M'Coy, 1844

Mark Thomas Warne[1]

Concerning the initial description of the crustacean/ostracod genus *Bairdia* M'Coy, 1844 from the Carboniferous of Ireland, Malz (1988) commented that 'McCoy was not aware of the importance of his discovery then, for as often happens great discoveries are evaluated much later.' Malz (1988) also mused that it was not until a lifespan later that the full importance of M'Coy's description of *Bairdia* became apparent (with the erection of the family Bairdiidae Sars 1888).

Interestingly, the original lateral view diagram in M'Coy, 1844 of *Bairdia curtus* (type species for genus) illustrates this species in an upside down fashion with respect to its probable original orientation in life (Fig. 1A).

Fossil specimens attributed to *Bairdia* range back in geological time to the Ordovician, with species of this genus becoming common in open shallow marine palaeoenvironments from the mid Palaeozoic (Fig. 1B). For many years the *Bairdia* generic concept was applied to younger post-Palaeozoic fossil and living ostracods with similar morphology – and some taxonomists still utilise this generic name for modern species. However, Cainozoic specimens of *Bairdia s.l.* have been split into a number of different genera by Maddocks (1966). In particular, the genera *Neonesidea* Maddocks, 1966 and *Paranesidea* Maddocks, 1966 (Fig. 1C) most closely resemble *Bairdia* – so much so that it may be argued that using the carapace as morphological grounds for distinguishing the former two from the latter are still questionable. This is largely a consequence of one of the most salient features of *Bairdia s.l.* ostracods – their subtrapezoid shaped carapace – which has

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remained a very dominant and conservative morphological feature throughout the evolutionary history of the Bairdiidae.

Bairdia s.l. group ostracods have been abundant and ubiquitous faunal elements of shallow marine realms throughout most of the Phanerozic with a few species becoming adapted to deep ocean environments from about the mid Cretaceous. They account for a significant component of modern day ostracod biodiversity. Indeed, so common are *Bairdia s.l.* ostracods in fossil and modern marine faunas that they can be considered as one of the most widespread and long ranging of all advanced life forms to have inhabited the earth.

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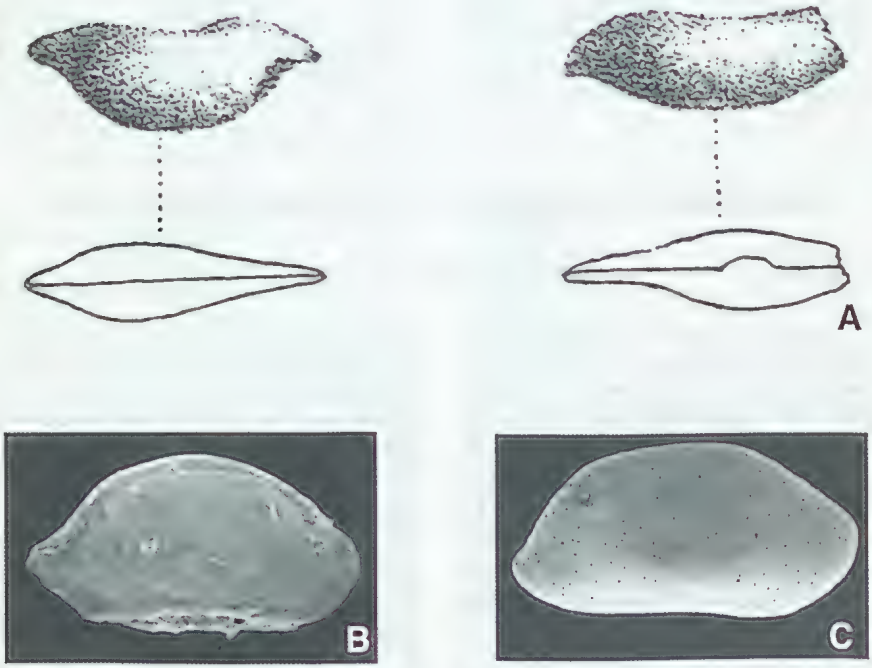

Fig. 1. A. Enlargement (×2.5) of illustrations of *Bairdia curtus* M'Coy, 1844 (Plate 23, fig. 6) and *Bairdia gracilis* M'Coy, 1844 (Plate 23, fig. 7). M'Coy recorded the length of *B. curtus* as being equal to 'one line'. M'Coy recorded the length of *B. gracilis* as being equal to 'half a line'. B. *Bairdia* sp. Carapace from Lower Devonian Buchan Caves Limestone outcropping near Lilly Pilly Cave, Buchan, eastern Victoria. Length of specimen is 0.60 mm. C. *Paranesidea* sp. Right valve from latest Upper Miocene Black Rock Sandstone intersected in Nepean 1 borehole at 178.3 metres depth (Nepean Peninsula, southern Victoria). Length of specimen is 0.65 mm.

A 'Bite' From the Past

Leigh Ahern[1]

During spring of 1999 I was fortunate to have the opportunity of assisting Mr A. J. (John) Coventry, the Officer-in-Charge of Herpetology at the Museum of Victoria, in carrying out re-labelling and other curatorial work on parts of the State herpetological collection, then housed at Abbotsford, near Melbourne. The task frequently involved checking to ensure that specimen naming was in accord (as far as practicable) with current taxonomy and that former references to the specimen (often as different taxa) in literature or historic museum registers were recorded on the museum's modern computerised database.

The work provided me with the opportunity to glimpse many preserved herpetological specimens dating back over the last 150 years or so. I was especially impressed by the number of fine snake specimens, many large and difficult to handle when alive, and often highly venomous, yet collected from some extremely remote parts of Australia. It was indeed a thrill to examine specimens still displaying the hand-written field labels of eminent naturalists of the past, including Gerard Krefft, Donald Thomson, Peter Rawlinson, and many others, and to view their additional contributions in the form of register entries and unpublished museum reports and notes.

An added benefit of working with John was the opportunity to marvel at the depth of knowledge gained during a career very purposefully dedicated to expanding and improving this State's herpetological collection. Under John's guidance, I often spent the lunch-hour perusing many of the Museum's literary gems on herpetology and wider natural history subjects. It was he who directed me to one of its most interesting holdings, the *Prodromus of the Zoology of Victoria* by Professor Frederick McCoy, published in successive parts between 1878 and 1890.

On one occasion I came upon an uncharacteristically damaged spirit-specimen—a snake labelled as *Diemenia superciliosa* (now known as the Western Brown Snake *Pseudonaja nuchalis*)—which had been donated by a 'Mr Strickland'. The unfortunate reptile appeared to have been all but chopped through in some four or five separate places along the body. The jar label referred to this specimen as having been 'figured' in Professor McCoy's *Prodromus*. Curious to understand what interest Professor McCoy might have had in such a poor specimen, I looked up the relevant Plate (23) in Volume I of the *Prodromus* (Fig. 1). The specimen had in fact only been used as one of a series of seven snakes from which morphological measurements had been tabulated for the species, and an 'average specimen' depicted.

Reading on, however, I discovered that Mr Strickland's specimen had a chilling relevance to the remarks made by Professor McCoy regarding contemporary treatments for the bite of this highly dangerous species. He wrote: 'In the experiments made by Dr Halford on snake-poisoning, tabulated in the *Medical Society's Journal* for March 1875, all the cases of people bitten by the Brown Snake and treated by the injection of ammonia recovered; but in one of the last cases mentioned in the public journals (*Bendigo Advertiser*, 27 October 1877), a snake of this species, 3 feet 6 inches long (the fifth in the above table of measurements), bit Mrs. Eleanor Ingleby, residing at Sebastian, in the hand, and she died from the effects within fifty minutes. The acting coroner, Mr. Strickland, who held the inquest, sent the specimen to the Museum, where it is now deposited, so that the species is determined with certainty.'

This incident, while illustrating what may have been a frequent tragedy in early colonial days, also highlights a seldom recognised feature of Victoria's natural history collections—namely, the stories associated with the collection itself. A surprising amount of fascinating historic detail was revealed to me even in the simple process of reviewing and rearranging the existing herpetological collection. Sadly, with every passing day, more of this rich historic detail

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recedes forever into dusty oblivion created by modern times and changing administrative priorities. Thankfully, Professor McCoy's *Prodromus* remains one means by which we can still experience at least a little of the former magic and adventure of Victoria's early inquiries into natural history.

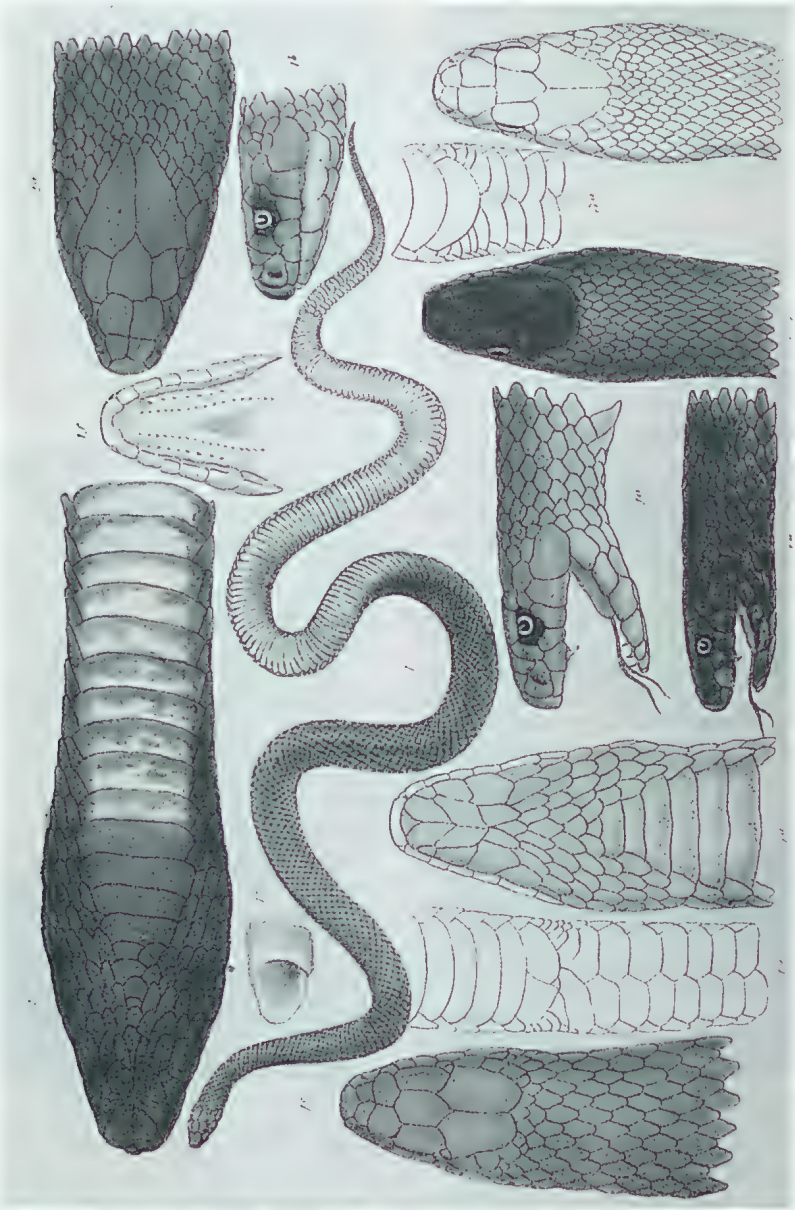

Fig. 1. The Common Brown Snake *Diemenia superciliosa* (fig. 1); Small-scaled Brown Snake *Diemenia microlepiodota* (McCoy) (figs. 2 & 3); The Shield-fronted Brown Snake *Diemenia aspidorhyncha* (McCoy). *Prodromus of the Zoology of Victoria*, Volume I, Decade III. Plate 23. Lithograph by A. Bartholomew and F. Schonfeld under the direction of Professor McCoy.

Frederick McCoy – the Challenge of Interpretation of Thylacoleonid Fossil Material

Bernard Mace[1]

Abstract
To 19th century biologists, Australia was a 'living museum' of marsupial species, and it became apparent that many of the extant genera were represented by fossils in the Tertiary geological strata of the northern hemisphere. Large marsupial carnivores were surprisingly absent from the extant fauna, except in Tasmania, and it was the palaeontologists, initially overseas experts exemplified by Professor (Sir) Richard Owen, who discovered that the Late Pleistocene was well served with marsupial carnivores. The most spectacular of all, and among the last to be verified, was *Thylacoleo carnifex* (Owen), the Marsupial Lion. The characterisation of this unique animal as a carnivore, rather than herbivore, omnivore or scavenger, was the subject of prolonged argument among experts of the time. Frederick McCoy was one of an emerging group of local scientists to enter the debate, and made an outstanding contribution. (*The Victorian Naturalist* **118** (6), 2001, 287-293.)

The apparent absence of large marsupial carnivores on mainland Australia has presented a puzzle to modern-day zoologists, but to 19th century palaeontologists the picture of extinct fauna was very different. Following the earliest days of biological discovery when the observations of Darwin, Banks and Baudin were building the foundations of scientific knowledge of the unique biology of this country, the layers of biological history and evolution were likewise beginning to be revealed by eminent palaeontologists of the time. Professor Richard Owen, Georges Cuvier, T.H. Huxley, Lydekker, Gervais and Clift were prominent overseas experts who analysed fossil material sent to Europe from Australia. Subsequently, an emerging body of Australian scientists, including Gerard Krefft, Professor Frederick McCoy, Professor J.W. Gregory, Henry Brown and Charles De Vis, contributed their interpretations to the growing body of overseas expertise, as the exploratory and geological expeditions yielded fossil records of an extraordinary prehistory (Rich *et al.* 1985)

It became apparent that the extinct marsupial fauna was characterised not only by a remarkable profusion and diversity of species, but also by the expected balance of carnivores and herbivores, at least well into the late Pleistocene. In this geologically recent period, the large physical proportions of representatives of extant genera observed in the fossil record contrasted markedly with the dimensions of present day fauna, and the term 'megafauna' was applied to marsupials of the past era, as it was to the extinct giant eutherian mammals of the northern hemisphere and the Americas. The size range of marsupial carnivora spanned diminutive dasyurids, through intermediate sarcophylids and thylacinids, and at the top of the food chain, with the capability of preying on even the largest macropodids and diprotodontids, was the remarkable creature *Thylacoleo carnifex* (Owen), the Marsupial (or Pouched) Lion. However, the process of interpretation leading to this conclusion was by no means uncontroversial.

The earliest knowledge of the existence of a lion-sized marsupial predator in Australia's prehistory was due to the analytical skills of Professor Richard Owen, who was presented with fossil teeth of an unusual nature by Major Thomas Mitchell in the 1830s. The fossil material was collected from the Wellington Valley area of New South Wales, having been gathered during the famous explorer's expeditions. Initially, Owen was unable to offer a solution to their identity. 'I could not, at that date, determine the affinities of the Australian mammal yielding such a tooth' (Owen 1877: 107). It was to take another 30 years for some clarity about the nature and 'affinities' of the enigmatic creature to emerge.

Subsequent fossil material from a tributary of the Condamine River, Queensland, and another find in 1846 from Lake

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Fig. 1. Thylacoleonid teeth and bone fragments sent to Owen in 1837 (from Owen 1877, fig. 1, plate VI).

Colungulac, Western Victoria, enabled Owen to begin to define the species and its habits (Fig. 1).

Following a lengthy analysis of the 'singular' but still tantalisingly incomplete fossil material he had at his disposal, Professor Owen summarises …

> and the chief conclusion as to the affinities of the animal to which they belonged, had been indicated by the term *Thylacoleo*, i.e. Marsupial or Pouched Lion, which conclusion was based on the characters and comparisons of those fossil remains detailed in the foregoing pages.
>
> The concurrence in them of so many cranial characters found only in the Marsupialia, will be deemed, I apprehend, demonstrative of the marsupial nature of *Thylacoleo*; and, amongst existing Marsupialia, the *Sarcophilus* or *Dasyurus ursinus* – at present the largest existing species of its genus – seems to me to have the nearest affinities to *Thylacoleo*, although the interval be still very great between them (Owen 1877: 120-121).

After examining additional fossil material, Owen became convinced that *Thylacoleo* was a carnivorous representative of the diprotodontids (Owen 1877: 131). By virtue of its extraordinary dental and cranial characteristics, he determined that this was a powerful, highly specialised carnivore.

> In existing carnivorous mammals, the ferocity of the species is in the ratio of 'carnassiality' of the sectorial molar, i.e. of the predominance of the 'blade' over the 'tubercle' … From the size and form of the carnassials of *Thylacoleo*, especially of the upper one, we may infer that it was one of the fellest and most destructive of predatory beasts (Owen 1877: 119).

Some 30 years later, Frederick McCoy received complementary thylacoleonid fossil material from the Lake Colungulac source in Western Victoria. Thus he became engaged in the process of interpretation of characteristics of this intriguing animal, and later contributed to the debate that had been raging amongst palaeontologists of the time, following the controversial published views of Professor Owen.

The problem of interpretation was heightened by the distinctive nature of the fossil teeth. Unusually large and well pointed incisors were complemented by extraordinary long shearing premolars resembling an efficient guillotine-like mechanism. Associated with these were two pairs of lesser incisors, small conical canines and, posterior to the large premolars, almost vestigial molars. This strikingly unusual dentition belonged to an animal with a heavily boned skull structure similar in size and musculature to a large pantherid such as the African Lion, to which Owen soon compared it (Owen 1877). Nothing was then known of the body structure of the animal, but by the time Owen had satisfied himself that he was dealing with a carnivore, some phalanges (toe and claw fragments) had been discovered and again they supported the flesh-eating hypothesis.

Owen noticed similarities in the dentition of *Plagiaulax* sp. (Owen 1877), a small carnivorous marsupial from known British Mesozoic fauna, to that of *Thylacoleo*, and it was this observation that led him strongly toward the marsupial carnivore diagnosis. *Plagiaulax* was determined to be a small, early mammal adapted to preying on small reptiles. It too exhibited stabbing incisors and shearing premolars (Fig. 2), indicating a high degree of 'carnassiality' (Owen 1877).

Fig. 2. Thylacoleonid teeth and mandible fragments which Owen compared to *Plagiaulax* shown (Fig. 10) on this plate (from Owen 1877, plate IX).

Owen presented his findings to the Royal Society of London, 15 June, 1865, and subsequently analysed and answered 'Objections to The Author's Determination of The Nature and Habits of The Species' (Owen 1877: 133).

> ... several eminent and experienced investigators of fossil remains have endeavoured to determine to which of the groups ... the *Thylacoleo* was most closely or immediately allied. Some have been led to the belief of its having been a Kangaroo, some have deemed it a Potoroo or Rat-Kangaroo, others would rank it with the arboreal Phalangers or Koalas; but all concur in repudiating its carnivorous character, having rejected the distinct section of Diprotodont Marsupials, of which *Thylacoleo* and *Plagiaulax* are exemplars, and have sought, with more or less ingenuity, to invalidate the conclusions which I have been led to deduce from the parts of the fossilized remains of those paucidentate Marsupials which at that date, had been submitted to my examination.

McCoy is not mentioned in this discussion, although it is clear from McCoy's (1862) *Prodromus* and other papers dealing with *Thylacoleo*, that he had no problems with Owen's carnivorous interpretation of thylacoleonid fossil material. One would think that Owen would have appreciated unequivocal support from a highly ranked colleague when it is considered that counter-arguments and conjecture regarding thylacoleonid affiliations and habits continued well into the 1900s. The following excerpt from McCoy's *Prodromus* indicates his clarity on the issue of carnivority, although his decision to describe the fossil material in his possession as a new thylacoleonid species was later deemed to be erroneous.

> There is no fossil animal yet described [that] has excited so much interest and given rise to so much animated controversies as that named the 'Marsupial Lion' by Professor Owen, from the general resemblances, on a greater scale, which the teeth of this marsupial animal show to those of the lion, and indicating, in his opinion, a similar predacious habit in each.

The tone of McCoy's expression gives an indication of his interest and enthusiasm for unravelling the mystery and debate surrounding the remains of *Thylacoleo*. Further, McCoy clearly sides with Owen in dismissing the opposing views of his detractors.

> Dr. Falconer, Mr Flower and others, have advocated, with singular zeal, the opposite view, that the creature was a harmless vegetable feeder ... overlooking the fact that these latter have a series of grinders of the ordinary type of vegetable feeders, behind the compressed premolar, while all the teeth are of the carnivorous type in the Marsupial Lion (McCoy 1876: 8).

McCoy received vital thylacoleonid fossil material from Mr Richard Adeney in 1876, found at Lake Colungulac (80 miles west of Melbourne) on his own property. It was suspected that the fossil material delivered to McCoy (Fig. 3) was part of the same skeleton that Adeney had found in 1846 when he provided incisor and premolar teeth along with fragments of the skull of a specimen which he had forwarded to Owen.

> A few months ago Mr Adeney brought to me the specimen figured in the upper part of our plate from the same spot, and so entirely completing the anterior part of the skull and teeth absent in the skull he found

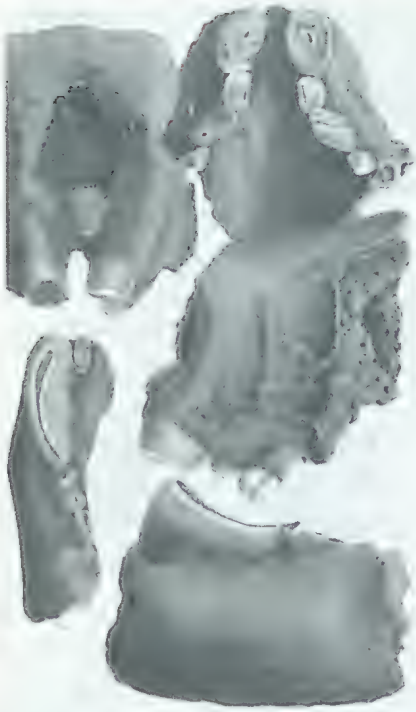

Fig. 3. Thylacoleonid fossil material supplied to McCoy by Richard Adeney, showing most of the teeth *in situ* (from McCoy 1876, plate XXI).

> nearly 30 years ago and sent to Professor Owen, that he supposed it might have belonged to the same individual (McCoy 1876: 9).

McCoy was emphatic about the importance of this material. 'Our present specimen is therefore the only one as yet made known exhibiting all the teeth in front of the carnassial in the upper jaw *in situ*' (McCoy 1876: 9).

He concluded that there was sufficient difference between this and another NSW specimen (from Wellington Caves) examined by Owen, to distinguish the Victorian fossil material as a new species, *Thylacoleo oweni*.

In his *Prodromus*, Decade III, McCoy put forward the following basis for that argument.

1. The longer convex margin of the third incisor was posterior in *T. carnifex* but reversed in *T. oweni*.
2. The position of the premaxillo-maxillary suture (seam or junction) in relation to the roots of the canine tooth and third incisor was significantly different (Fig. 4) (comparing NSW to Victorian source material).
3. The depth of the mandibular ramus (principal bone section) in the region supporting the shearing premolar (P3) and first molar (M1) was greater toward the front in the Victorian specimen, and toward the rear in the NSW specimen.
4. The palate was narrower and longer in the Victorian specimen.
5. The first and second incisors and the canines were larger in the Victorian specimen.

McCoy's exhaustive analysis thus led him to believe he was justified in naming a new species, *Thylacoleo oweni* (McCoy 1876: 7-11), but it was not long before Owen (1877) rejected the first two points on the basis of:

1. His own initial interpretation of the orientation of the third incisor was based on detached teeth. This was later corrected after receipt of more complete fossil material.
2. Uncertainty over identity of the third incisor and canine (for similar reasons to above) was also cleared up after examination of further material.

Later, more detailed analysis (Archer and Dawson 1982; Finch 1982) confirmed that all of the points of distinction raised by McCoy were within the range of variability found in the now extensive *Thylacoleo* fossil collection from the Wellington Caves area of NSW This showed conclusively that there was no longer any justification for maintaining that different species existed in Victoria and NSW

However, on-going research by modern-day palaeontologists has confirmed the family Thylacoleonidae is represented by at least nine extinct species, incorporated in three genera (Gillespie 1999). The oldest and smallest is *Priscileo*, known from specimens representing two species from late Oligocene and early Miocene deposits. The 'mid-sized' *Wakaleo* is known from fossil material of late Oligocene to late Miocene sources, representing four species (Gillespie 1999). Three species of *Thylacoleo* have thus far been identified. *T. hilli*, the smallest and oldest, is known from late Pliocene origins, and was known

Fig. 4. 'Reduced side view showing direction and character of the premaxillo-maxillary suture dividing the socket of the canine' (from McCoy 1876, fig. 2, p. 10).

to have coexisted with the larger *Thylacoleo crassidentatus*. The most recent, and by far the largest representative, was *Thylacoleo carnifex*, known from early to late Pleistocene (Archer and Dawson 1982; Gillespie 1999). The most recent fossil material appears to be that originating from a cave near Montague, north-west Tasmania, which is dated at approximately 10,000 years bp (Finch and Freedman 1982; Murray and Goede 1977). Along with the apparent progressive increase in size of thylacoleonids from the late Oligocene to the late Pleistocene, there is also a progressive increase in the degree of specialisation of their dental characteristics. This reached a peak in *Thylacoleo carnifex* with its huge shearing premolars (up to 5 cm long), that moved Owen to describe it as 'the fellest of beasts.' (Owen 1877).

Detailed studies of the structure and development of wear patterns on the teeth of *Thylacoleo carnifex* (Wells *et al.* 1982), confirmed once and for all, that 'All evidence pointed to a flesh-eating marsupial of diprotodontid ancestry,' not a plant eater. In this study, they compared the striations produced by the passage of food across the tooth enamel of known carnivores and herbivores, with reference to similar markings on the teeth of *Thylacoleo* (Wells *et al.* 1982). This enabled them to clearly define the piercing function of the first incisors, as well as the shearing function of the carnassials (premolars). An extraordinary adaptation, peculiar to *Thylacoleo* amongst mammalian carnivores, is the apparently unfused ramus (mandible), providing for a 'flexible symphysis' (Wells *et al.* 1982). This allows for limited rotation of the lower premolars about the longitudinal axis, optimising the interface angles of the upper and lower shearing surfaces during jaw closure. It also implies the possibility of separation of the lower incisors into an open 'V' during delivery of the powerful piercing bite, perhaps providing a more secure hold on prey than had been previously postulated.

The analysis of more recent finds of post-cranial material, particularly a near complete skeleton found at Moree, NSW in 1966, has enabled palaeontologists to determine the general appearance and to speculate on the habits and lifestyle of this most unusual predator. Recent empirical research based on skeletal dimensions, particularly circumference of femur and humerus of the Moree specimen (Wroe *et al.* 1999), clearly indicates that *Thylacoleo carnifex* lived up to the pronouncements and expectations of Owen, in that it rivalled the African Lion in size, weight and strength. The method was considered reliable in predicting weights of living and extinct fauna, enabling the research team to conclude that this formidable carnivore, sometimes topping 160 kilograms in weight, was most likely a big game specialist with the capability of killing even the diprotodontids (Wroe *et al.* 1999).

The complete profile of this top carnivore is still emerging from continued study of fossil material from more diverse sites. The spinal column has been described as robust but flexible, with a strong neck, supporting a large head (Finch 1971). We now have a picture of a heavily built quadruped with relatively long limbs, exceptional musculature, a long flexible tail and perhaps a lithe, cat-like overall appearance. Aboriginals of the 'dreamtime' who had the dubious privilege of

encountering this snarling beast would have perceived large, forward-set eyes providing good binocular vision, huge ice-pick incisors and extraordinary blade-like carnassials in an animal that possibly had agility commensurate with its pantherid size and approximate conformation (Fig. 5). Haunting impressions of the legendary 'drop bear' are brought to mind.

The five-toed front paw structure incorporated a very heavy first digit with large hooded claw, which was opposable toward the wrist (Wells and Nichol 1977). There are indications that the claws are partly retractile, and if so this takes an already apparent evolutionary parallel with the big cats to another challenging level. These adaptations would have served just as well in grasping prey as in climbing trees, so both applications have been considered to be within the range of accomplishments of this Pleistocene hunter. The hind foot has been described as possum-like with an opposable first digit, which again suggests arboreal capabilities (Wells 1985). Recently it has been suggested that the size and weight of *Thylacoleo carnifex* counts against an arboreal inference (Wroe *et al.* 1999). However, some consideration must be given to the recent discovery of excellent tree climbing skills of adult male Lowland Gorillas *Gorilla gorilla gorilla,* that can weigh upwards of 200 kg. This unexpected behavior has recently been filmed in Congo rainforests (BBC Wildlife, 2001), and highlights the importance of grasping adaptations that would seem to have advantaged *Thylacoleo* in any arboreal aspirations. Finally, with the combination of digitigrade stance on the front paws, and possibly plantigrade hind feet, it has been suggested that *Thylacoleo* could have had a good turn of speed, at least in short bursts, in pursuit of its prey (Finch 1982).

Thylacoleo fossils have now been identified in nearly every major late Pleistocene fauna site in Australia (Wells 1985), but usually in small numbers compared to herbivorous representatives of the marsupial megafauna. This is in keeping with a top carnivore's predator/prey population dynamics. The major exception is Victoria Cave, Naracoorte SA (Wells 1985; Wells and Nichol 1977) where numerous near complete skeletons have been identified in one precise location.

Some conclusions regarding predation have been drawn from associations between thylacoleonid fossil remains and possible prey species found at the same locations. *Sthenurine* kangaroo bones have been found with grooves corresponding to the distinctive dentition of *Thylacoleo* (Horton and Wright 1981). Similar occurrences from other fossil sites dating back to the 1800s (DeVis 1883) supports this conclusion. A diprotodon femur exhibiting compelling evidence of two biting attacks (indicative of *Thylacoleo*), from two directions, with subsequent evidence of healing (Scott and Lord 1924), represents the only current evidence of *Thylacoleo* preying on live megafauna (Fig. 6). Evidence contin-

Fig. 5. *Thylacoleo carnifex* depicted in this interpretation by scientific illustrator Peter Schouten as arboreal and distinctly cat-like. From Finch (1983). Reproduced with permission.

Fig. 6. *Thylacoleo carnifex* depicted preying on *Procoptodon* by scientific illustrator Peter Schouten. From Finch (1983). Reproduced with permission.

ues to grow in support of the logic and deductive processes of Owen and McCoy more than a century ago.

The picture has finally come together of a widespread, powerful and highly successful predator, possibly with related species occupying a range of ecological niches provided by the incredible diversity of the associated megafauna, as in the realm of the felids of the northern hemisphere. Evocative as this image is of a Pleistocene marsupial paradise, it was shattered by the mass extinctions corresponding to the end of that Epoch, and, for reasons yet to be determined, the apparently adaptable family of thylacoleonids went into oblivion along with the lost marsupial giants.

This brief review of the part played by Frederick McCoy in unravelling the phylogenetic associations and feeding preferences of *Thylacoleo carnifex* (Owen) has led us to an appreciation of his clarity in supporting Owen's original determination of a carnivore of diprotodontian 'affiliations.' Many of his contemporaries who staunchly advocated alternative theories have progressively been proven wrong by the application of modern scientific methods. However, those early counter-arguments occupied present day palaeontologists well into the 20th century before they could be unequivocally put to rest.

McCoy's apparent haste in proclaiming *Thylacoleo oweni* as a distinct species may have signalled his anticipation that relatives of Owen's Marsupial Lion could have had a place in the diverse fauna of the Pleistocene.

Acknowledgements
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M'Coy and the Australian Ichthyosaur *Ichthyosaurus australis* (M'Coy, 1867)

A.J. Hell[1]

Abstract
The first Australian ichthyosaur fossils were described by Frederick M'Coy in 1867 from a series of fossil specimens collected by James Sutherland in the Flinders River region, northern Queensland. An initial case of fossils collected was primarily used by M'Coy to provide the first incontrovertible proof of the existence of the Cretaceous System in Australia. Subsequent follow-up work was undertaken and further specimens were collected, including fossil vertebrae that were named by M'Coy, *Ichthyosaurus australis* (M'Coy 1867). Despite describing the species as 'the most interesting fossil animal yet found in Australia' his descriptions were brief and limited and have been criticized by a number of later workers. (*The Victorian Naturalist* **118** (6), 2001, 294-297.)

Frederick M'Coy's description of the first ichthyosaur fossils in Australia (M'Coy 1867a) (Fig. 1) are generally considered to be an important contribution to Australian vertebrate palaeontology. The three boxes of fossil material M'Coy described were collected by James Sutherland during the period from early January 1865 through to November 1866 (Sutherland to M'Coy 1865 & 1866). The fossils were all collected from the Flinders River region at Lat. 21° 13'S and Long. 143° 25'E (M'Coy 1865), north Queensland and as described by Sutherland were,

> collected between Walker & O'Connell Creeks left bank of the river. (See Landsborough Map) in the dry channels & water courses but principally on the slopes of the undulations or ridges & outer summits lying detached in the loose earth (letter from Sutherland to M'Coy, 7 October 1865).

Despite M'Coy being held in high regard for his contributions to Irish, British and Australian palaeontology, his published works on the Australian ichthyosaur does little to enhance his reputation.

Based on his brief and limited descriptions and lack of illustrations, it is apparent that this was a hasty attempt to record and document a new species and its implications for the recognition of the Cretaceous System in Australia. Many workers (Etheridge 1888, Longman 1922 and Wade 1984a; b; 1990) involved with researching the Australian ichthyosaur are critical of M'Coy's published works. McGowan (1972) suggested that Etheridge's (1888) work on ichthyosaurs, in which he gives a very detailed description of his material and erects a new species, was 'probably out of the sense of frustration and despair at trying to compare this material with M'Coy's' (McGowan 1972). For the contemporary worker it is not easy to decipher and relate M'Coy's descriptions to the specimens that he described. It is especially difficult to identify from the collection the original type fossil vertebrae (M'Coy 1867a, Sutherland to M'Coy 1866). Furthermore, the present author examined and separated what are assumed to be the original fossil vertebrae, and found many inconsistencies with M'Coy's measurements. However, with much patience, it was found that some of the specimens match M'Coy's descriptions, but overall his work is notably vague and 'meagre' (Etheridge 1888).

The ichthyosaur species described by M'Coy was considered by him to be the 'most interesting fossil animal yet found in Australia' (M'Coy 1868b), suggesting that his descriptions were only preliminary and given simply to acknowledge existence of the species in the country. If we were to compare this work with much of his other works, one may assume that M'Coy intended to undertake further detailed and illustrative contributions on the ichthyosaur fossils. Unfortunately however, probably based on many contingencies, further published works were not undertaken, and therefore what remains is a significant but sketchy description.

The first case of Sutherland's fossil specimens described by M'Coy (1865), as far as the author is aware, did not contain

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Fig. 1. *Platypterygius australis*. Interpretation of a Australian Cretaceous ichthyosaur 'after the Telemon specimen and others. Length over all 5.6m' (Wade 1984a).

ichthyosaur fossils and essentially comprised molluscs, ammonites and fish vertebrae. These specimens, however, occurring in 'an olive calcareo-argillaceous marl' (M'Coy 1866), played an important role in Australian geology, allowing M'Coy to indisputably confirm for the first time in Australia the Cretaceous formation (M'Coy 1865; 1866). Shortly after this recognition, Sutherland carried out further collection work in the same area. During this time Sutherland made a discovery of fossil vertebrae which he believed to be 'saurian'. Among the specimens collected by Sutherland, the vertebrae sections were considered of significance, about which he wrote to M'Coy on the 7 October 1865,

> The collection now on its way will I think determine the age of the formation. It's a certainty; it consists – chiefly of molluscs, fishes and reptiles. The most remarkable are to me vertebral joints from 3 to 4 inches diameter, probably Saurian.

M'Coy first published on his material in England, and possibly pressured by the nature and timing of 'sailing ship mail runs' (Wade 1984b) he presented an initial brief and hasty description of the species. However, as Sutherland indicated to M'Coy (Sutherland to M'Coy 1865) the initial collection of ichthyosaur vertebrae including other fossils were likely to be delivered by the end of December, 1865. This would have given him adequate time for a detailed description, but of course it is possible they arrived much later. M'Coy's first publication on the species entitled: 'On the Occurrence of Ichthyosaurs and Plesiosaurs in Australia' was published in the *Annals and Magazine of Natural History* (M'Coy 1867a), which he later presented in the *Transactions and Proceedings of the Royal Society of Victoria*, entitled: 'On the Discovery of Enaliosauria and other Cretaceous fossils in Australia' (M'Coy 1868a). Due to the nature of communication and travel time, further information on more ichthyosaur specimens (Sutherland to M'Coy 1866) collected by Sutherland, did not reach M'Coy prior to his first publication.

M'Coy received a third and final collection of ichthyosaur specimens from the same area, sent by Sutherland in November 1866. This collection was the most significant, and comprised more discernable skeletal material including two skull sections (Fig. 2), sections of vertebrae, rib bones, paddle fragments and a section of the jaw with exposed teeth (Fig. 3). Both M'Coy and Sutherland's recordings and descriptions, were limited in part, making it difficult to contrast and compare information to the actual type material. The entire collection, with original sample numbers 48 and 60, can be viewed in the Museum of Victoria. Wade (1984a) stated that M'Coy's description was such that, '... it is imposible to discover that it contained two skulls'. After examinng the type material, the author believes that M'Coy thought the two specimens (MV P12990 and P12989) belonged to the one skull. However, it remains an open question as to whether the two skull sections are from the same individual.

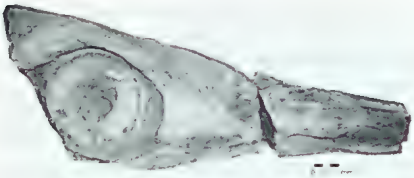

Fig. 2. *Ichthyosaurus australis* (M'Coy 1867). Two sections of the skull displaying the characteristic large eye with well preserved sclerotic plates, MV P12990 and P12989.

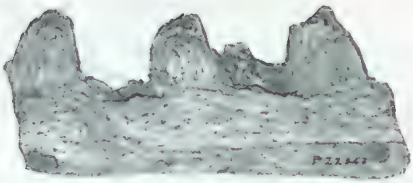

Fig. 3. *Ichthyosaurus australis* (M'Coy 1867). Section of jaw with exposed teeth, MV P22653.

M'Coy's final publications on the Australian ichthyosaur were based on the skull, forelimb and other vertebrae sections. He published these findings in the *Intercolonial Exhibition of Australasia, Official Record* (M'Coy, 1867b) later reprinted in the *Annals and Magazine of Natural History* (M'Coy 1867c). Descriptions of these additional specimens were also published in the *Transactions and Proceedings of the Royal Society of Victoria*, entitled: 'On the Fossil Eye and Teeth of the *Ichthyosaurus australis*, (M'Coy), from the Cretaceous formations of the source of the Flinders River ...' (M'Coy 1868b).

The more notable aspects of M'Coy's descriptions in the later publications were his interpretation of the form and functional morphological characteristics of the species. 'Some bones now exhibited prove this species to have been one of the largest of its genus, one individual being from analogy, (25) feet in length' (M'Coy 1868b). Furthermore, referring to the paddle fragments, 'it has (8) eight rows of phalangeal bones, and as one edge is imperfect, it may have had more; it is thus one of the most powerful swimmers of the genus' (M'Coy 1868b).

The first published illustrations of M'Coy's type specimens were figured by Chapman (1914) who illustrated one each of the skull (MV P12990) and forefin fragments. Anderson (1934) and McGowan (1972) later figured M'Coy's material. It is conceivable that M'Coy may have intended at a later date to produce a more comprehensive work including illustrations of the type specimens. However, there is no evidence to support this.

M'Coy's work on the Australian ichthyosaur has been criticized by a number of past and contemporary workers. Although M'Coy's overall contribution to taxonomic palaeontology is extensive and praiseworthy, his work on the Australian ichthyosaur appears to be brief and limited. It is possible that M'Coy saw his descriptions only as preliminary and that he intended, if time and finances permitted, to carry out a more considered and accurate examination of the fossils in question.

Acknowledgements

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Animal Acclimatisation: McCoy and the Menagerie That Became Melbourne's Zoo

Linden Gillbank[1]

Abstract

Frederick McCoy's mid-nineteenth century zoological interests included animal acclimatisation. He helped shape the menagerie in Mueller's Botanic Gardens and later in the Acclimatisation Society of Victoria's Royal Park depot, where it grew into Melbourne's zoo. He was particularly interested in three animals shipped from India – the Cashmere goat, Arrindy silkworm and Indian Minah. (*The Victorian Naturalist* **118** (6), 2001, 297-304.)

Introduction

Frederick McCoy is known as a university professor and museum director, but his involvement in another institution – Melbourne's zoo – is less well-known. He helped shape its presumptive menagerie – a transient collection of animals awaiting permanent homes elsewhere. These animals were not primarily for display. They were brought into the young colony of Victoria by a society dedicated to the introduction of useful and ornamental animals and plants, in the hope of enriching the purses and psyches of immigrant colonists – birds that would sing sweetly or consume fruit-attacking insects, fish for Victoria's rivers, and game and grazing animals for bush and paddocks.

McCoy's mid-nineteenth century acclimatisation interests and activities, as revealed in zoological and acclimatisation society records, provide glimpses of the origins of Melbourne's zoo and of the global acclimatisation movement. They contrast starkly with current environmental and ecological ideas.

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Acclimatisation

As Victoria's gold production declined during the 1850s, new rural industries were sought. What could graze or grow in the colony? And there was nostalgia. So far from the sights and sounds of European 'home', immigrant Victorians wanted to hear the skylark and nightingale, and see and shoot deer, pheasants and partridges. 'New' useful and attractive animals were eagerly sought for pleasure and production.

The Acclimatisation Society of Victoria was established in 1861 to fulfill these economic and nostalgic desires. At its Royal Park depot sea-weary animals recovered prior to their distribution across the colony. A lifelong member, McCoy served on the Acclimatisation Society's Council from 1861 until 1872, the year that Zoological was added to the Society's title. The Council acknowledged its great indebtedness to McCoy 'who in spite of the multifarious calls upon his time and attentions has always rendered to this Society services of a valuable and scientific character' (ASV 1864: 12), and that the vice-presidency was 'unanimously conferred upon Professor McCoy, who has been a warm friend to acclimatisation

from the very first in this country' (ASV 1866: 5).

Agreeing to give the Society's first annual address in November 1862, McCoy presented his ideas on acclimatisation (ASV 1862: 36-9). It did not, he said, necessarily mean the possibly difficult alteration of a creature's tolerance to different climatic or geographic conditions, but rather

> the bringing together in any one country the various useful or ornamental animals of other countries having the same or nearly the same climate and general conditions of surface.

On a map of the world he pointed to places, separated by climatic or geographic barriers, which were inhabited by similar animals – the 'representative species' created there – and displayed museum specimens of them. The acclimatiser could 'bring with the absolute certainty of success *all* the representative species of any group into *each* of the localities'. This, he said, was 'the first great principle involved in successful acclimatising'.

He presented a gastronomical glimpse of biological diversity:

> Of the quadrupeds useful for food, by far the largest number and most important to the acclimatiser, belong to the great group of ruminating animals which chew the cud, and have a cloven foot.

So many ruminants occurred within Australian latitudes on other continents. The fifty in India included 'upwards of twenty species of deer, six antelopes, and various species of sheep, goat, ox, &c', and South America provided 'three species of llama and alpaca, eight species of deer, and a goat'. But it was an 'extraordinary fact'

> that while Nature has so abundantly furnished forth the natural larder of every other similarly situated country on the face of the earth with a great variety, and a profusion of individuals of ruminants good for food, *not one single creature of the kind inhabits Australia*!

Furthermore

> If Australia had been colonised by any of the lazy nations of the earth, this nakedness of the land would have been indeed an oppressive misfortune, but Englishmen love a good piece of voluntary hard work, and you will all, I am sure, rejoice with me that this great piece of nature's work has been left to us to do.

The young society had grand intentions and much to do.

Melbourne's Menagerie – alpacas but not lions

Before the birth of Victoria's acclimatisation society there were various attempts to introduce animals new to Victoria, including those of Edward Wilson (co-owner and retired editor of the Melbourne *Argus*) in Victoria's Philosophical Institute and in England (Gillbank 1996a). And there was an impecunious zoological society which was unable to keep its growing menagerie.

Soon after its formation in October 1857, the Zoological Society of Victoria was promised money and granted land in Richmond Paddock north of the Yarra. When a later government refused to honour its predecessor's substantial pecuniary promise, the Society was unable to convert its land into zoological gardens, leaving its assorted animals high and dry across the Yarra in the Botanic Gardens. After much worrying, discussing and not paying the labourers who dug and fenced its swampy site, the debt-ridden Zoological Society handed over control of its land and animals to the government, which then agreed to provide funding; and government and Zoological Society representatives were appointed to a management committee (Gillbank 1996b).

McCoy was one of four government appointees to the Zoological Gardens Management Committee which, from July 1858 to August 1861, held monthly meetings in Dr Ferdinand Mueller's office in the Botanic Gardens, and later in Melbourne's Mechanics Institute. Mueller, the government botanist and director of the Botanic Gardens, was the Zoological Committee's honorary secretary, whose minutes of meetings record McCoy's attendance at seven meetings and his comments on lions, glow worms and a ruminant – the Cashmere goat.

At the Zoological Committee's first meeting in July 1858 McCoy

> expressed his great desire of seeing in future the botanic and the zoological Gardens combined, in as much as he regarded the higher and already planted grounds of the botanic Gardens more suitable to the health of the generality of the Quadrupeds.

After the October meeting's resolution to combine the two grounds, Melbourne's Botanic Gardens gained land as well as animals and Mueller signed his annual reports as director of the botanic and zoological gardens.

In 1858 McCoy was also a member of the Exploration Committee of Victoria's Philosophical Institute (Royal Society from 1860) which wanted camels for the grand transcontinental exploration expedition it was organising (Bonyhady 1991). He chaired the Zoological Committee's August meeting which agreed that camels should be acquired and heard George Landells' offer to import them. In December 1858 the Zoological Committee discussed the claim of the enterprising entrepreneur of Cremorne Gardens Amusement Park in Richmond, George Coppin, that he had two lions for the Zoological Society and was awaiting payment. On McCoy's suggestion the Committee decided to investigate his claim. Later they decided against accepting the lions.

While it was difficult to find money for such impressive animals as lions, government money was available for the introduction of useful ones – £500 in 1860. McCoy chaired the Zoological Committee's June meeting which welcomed Landells' arrival with 24 camels. On 20 August 1860, while Melbournians flocked to Royal Park to farewell these very useful animals with Burke and Wills, and the rest of the over-encumbered expedition, the Zoological Committee heard from another animal trader, Charles Ledger, offering to import alpacas. They decided to seek government money for Chinese sheep and Cashmere goats, but not alpacas. McCoy successfully proposed that £200 should be sought for the introduction of Cashmere goats, which because of their wonderful wool were also called shawl goats. In October Mueller reported payment of £200 to Messrs Grice, Sumner & Co (the Melbourne merchant firm of the Committee's honorary treasurer, T.J. Sumner) for their importation.

Alpacas also produce fine wool. In 1859 the Zoological Committee received a mixed llama-alpaca flock which Edward Wilson sent from England (Gillbank 1996b). Unfortunately, unlike the NSW flock which Ledger spent a very difficult decade collecting in Peru and smuggling across the great South American Cordillera (Gramiccia 1988), the Committee's flock contained very little alpaca. In October 1860 Ledger brought two male alpacas to breed better wool into the Zoological Committee's flock, and joined the Committee's deputation seeking government money for alpaca importation. McCoy chaired the November meeting which heard that the Chief Secretary had promised to bring the matter 'under the favorable notice of the Cabinet and to place the requisite sum on the estimates'. The subsequent granting of the huge sum of £2000 was a hopeful beginning to the sorry saga of Ledger's blighted attempt to bring alpacas to Victoria, as revealed in Zoological Committee minutes and by Gramiccia (1988).

By the end of 1860 Melbourne's Botanic Gardens supported an interesting menagerie. In his annual report Mueller (1861:10) recorded the following exotic and indigenous animals:

> Llamas, Angora goats, fat-tail sheep, elk, fallow deer, Sumatra deer, Ceylon deer, four species of monkeys, kangaroos, wallabys, two species of kangaroo-rats, English squirrels, two species of flying squirrels, two species of Australian opossum, Indian screwtail, native bears, Indian and Australian porcupines, wombats, water-moles, emus, white and black swans, Chinese geese, Muscovy ducks, spoonbill ducks, Cape Barren geese, one Indian pelican, native companion, one Indian heron, curlews, laughing-jackass, magpies, three species of native owls, three species of native hawks, Australian eagles, Murray pheasants, silver pheasants, British pheasants, Manilla and two species of Feejee doves, ring-doves, bronze-winged pigeons, Indian mocking birds, Indian and British partridges, hedge-sparrows, linnets, canary birds, skylarks, goldfinches, siskins, blackbirds, thrushes, Java sparrows, Australian and Californian quail, one iguana.

And perhaps there were glow worms. For several years Edward Wilson was very busy in England orchestrating the transmission to Melbourne of an amazing variety of creatures, and in 1860 sent glow worms. At the Zoological Committee's November

meeting McCoy suggested that some be liberated in the Botanic Gardens and some hatched at the National Museum of Victoria in the University grounds, where he later found a missing but apparently acclimatised one in full glow (ASV 1862).

As an increasing diversity of animals reached Melbourne's Botanic Gardens another site and another society were in the minds of their managers. As Landells' camels left their Royal Park stables on the ill-fated expedition, Royal Park was considered as an alternative site for zoological gardens (Gillbank 1996b). But Edward Wilson, the font of much acclimatisation wisdom and activity, was still in England. On his return a new society devoted solely to acclimatisation could be established. At a special meeting on 27 February 1861 the Zoological Committee reconstituted itself the committee of the Acclimatisation Society of Victoria, which two days earlier had been formed at a public meeting presided over by the governor, Sir Henry Barkly.

From February to August 1861 acclimatisation activities and animals were transferred to the new committee. After attending the Zoological Committee's May meeting which resolved to ask the Chief Secretary for the large sums recently granted for acclimatisation – £2000 for the introduction of alpaca, £500 for salmon and £500 for other useful animals – McCoy attended the Acclimatisation Society's committee meeting which, not surprisingly, decided that this money should be made available to them. Minutes of the Zoological Committee's last meeting in August 1861 record the transfer from the Botanic Gardens to Royal Park of Angora goats, Chinese sheep and llama-alpacas, and consideration of 'the cession of the Royal Park to the Acclimatisation Society'.

The Acclimatisation Society of Victoria (ASV) and a goat, a silkworm and a bird from India

At a public meeting in August 1861 Edward Wilson was appointed president and Mueller vice president of the Acclimatisation Society of Victoria (ASV). McCoy was a committee member of the ASV Council and Governor Barkly agreed to be patron. The ASV attracted thousands of pounds of government money and hundreds of members. Consuls were made honorary members. ASV Council meetings were held in the Society's city office or sometimes in the Camel House at Royal Park before inspecting the menagerie.

The minutes of its weekly meetings reveal how busy the ASV Council was – organising the importation of a great diversity of useful animals, their transient accommodation at Royal Park, and their transfer to land, water and sky elsewhere in Victoria. The ASV's primary object was not a fascinating zoological display at Royal Park, but rather the distribution of creatures across the colony. At its Royal Park depot newly-arrived animals recovered from long and often debilitating sea voyages, and, if possible, reproduced. Breeding was important because successful acclimatisation required enough individuals to sustain viable populations in their new homes. If Royal Park was not suitable, breeding grounds elsewhere were sought. Death was not wasted. Animal corpses became stuffed specimens in the National Museum of Victoria. Lucky McCoy!

In the early 1860s McCoy attended about half the ASV Council meetings, during which he shaped resolutions and participated in subcommittees. His successful resolutions in 1862 included

> That £500 be placed at the disposal of the President in Europe ... for the purchase of birds and quadrupeds likely to thrive and do well when turned out in the colony [20 May];
>
> That a paragraph ... be inserted in all letters to foreign correspondents, viz ... that the Council are very desirous of obtaining chiefly animals and birds of an economically useful character, and those native birds already domesticated in your locality whether for ornament, song or use, and examples of the game of your country are most particularly desired [17 June];
>
> That no imported animals of useful or ornamental kinds be sent out of the colony in the way of exchange unless where such imported specimens have been procured by the Society as authorised agents for other governments or persons [30 December].

In 1862 McCoy was appointed to subcommittees

> to enquire and report as to the most suitable locality for a breeding camel park, preparatory to an application to the Government for a grant of land for that purpose [3 June];
> to visit the [Royal] Park and report to the Council upon the present arrangements in force there and to make any suggestions to the Council they may deem advisable [26 August];
> to visit the Park and report what animals can be got rid of as useless and how far the present expenditure can be reduced [2 October];
> to report to the Council on those animals for the introduction of which it is most desirable at present to expend the funds of the Society [9 December].

McCoy's resolutions and sub-committees indicate the thrust of the ASV. Council minutes also reveal McCoy's acclimatisation interest in three creatures shipped from India – the Cashmere goat, a silkworm and a bird.

While waiting for Sumner's company to acquire Cashmere goats, the ASV received several from Ledger. At an ASV Council meeting in December 1861 McCoy heard Ledger's promise to send several Cashmere goats he had offered the Zoological Committee (and his request for the balance of the government's £2000 for alpaca importation), and in February 1862 that three goats had arrived. Later, when Ledger's alpaca activities attracted stinging suspicion, McCoy prepared explanatory resolutions and joined deputations aimed at extricating the ASV from their dealings with Ledger without losing the whole £2000.

ASV Council minutes reveal the involvement of a Calcutta company – Messrs Gillanders, Arbuthnot & Co (which began seeking Cashmere goats for the Zoological Committee in 1861) – and that, after hearing in March 1862 Sumner's company's question about advertising in Calcutta newspapers, McCoy re-initiated action. On 3 June he successfully moved

> That Mr. Sumner be requested to purchase through his firm in India pure Cashmere shawl goats to the extent of the £200 now in his hands and that application be made to the Government for a run on a Gipps Land mountain with a sufficiently low temperature to favor the best development of the fleece of Llamas, Alpacas and Cashmere goats.

While the Calcutta company remained willing to procure Cashmere goats for the ASV, the Victorian government claimed that it had no suitable unoccupied land for them and suggested Angus McMillan in Gippsland. In October 1862 McCoy attended ASV Council meetings which decided that the goats should be sent to Gippsland and heard from the Calcutta company that C.B. Chalmers was collecting Cashmere goats for introduction into Australia. In his ASV annual address in November McCoy was pleased to report that

> in a few months we expect a large number of the pure Cashmere-shawl goat, from Thibet, which have been already purchased for the Society, with the intention of forming a great herd on some of the highest mountains of Gipps Land, which retain snow sufficiently long to produce the temperature necessary for preservation of the finest qualities of the wool and hair' (ASV 1862: 50).

ASV Council minutes and annual report in 1863 chart Cashmere goat movements. Chalmers brought half the flock to Melbourne, leaving the other half sweltering in Calcutta until the next mail steamer left. At Royal Park on 21 April the ASV Council thanked Dr Chalmers profusely for his 'invaluable services in procuring the Cashmere goats for the Society' and inspected them. McCoy attended the next meeting which decided to ask William Degraves if the goats could stay on his station at Omeo. On 5 May McCoy reported a goat death and heard that Degraves would accept the goats provided 'the Society paid all expenses and gave him a fair proportion of the increase'. His offer was declined. W.G. McCullough of Maryborough had earlier offered to take the goats, and Sumner suggested that, provided he paid all expenses, he should be allowed to take them, thus freeing the Society's funds for other purposes. On 12 May McCoy heard that the second lot of Cashmere goats (21 goats and two kids) had been shipped from Calcutta; and on 16 June that 17 goats and four kids had reached Melbourne. They were extremely weak and ill. The ASV annual report recorded the purchase of 49 valuable-fleeced Cashmere goats which

Chalmers had collected (and, like Ledger, smuggled out) and transported thousands of miles in nine exhausting months to Calcutta. Many, including the whole second consignment, died, leaving only 25 at Royal Park late in 1863 (ASV 1863).

ASV Council minutes record goat illness and recovery, births and deaths. McCoy examined them. In July 1863 he attributed several deaths to 'excessive debility caused by skin disease' and recommended treatment 'as for the scab' (which was ravaging Victorian sheep flocks). On hearing that McCullough would take the goats provided he receive half of any increase, the ASV Council decided on 17 November 1863 to send them to him. At the next meeting McCoy heard that they had reached Maryborough safely. McCullough kept the ASV informed of flock increases. At a Council meeting in May 1864 McCoy heard of four recent births, and in December that the flock had grown to 30. They were reputedly thriving at Maryborough (ASV 1864).

But all was not well. In May 1865 McCullough wrote offering his portion of the flock at cost price. However the ASV Council 'did not feel disposed at present to expend any further money on Cashmere goats'. In July McCullough returned the goats to Melbourne. They were in very poor condition and several were Angora-Cashmere crosses. In his accompanying letter McCullough regretted some accidental cross-breeding. In December 1865, 27 Cashmere goats were recorded as Royal Park residents (ASV 1866).

Another desired textile was silk, and in the 1860s there were great hopes for sericulture in Victoria. McCoy was interested in an Indian silkworm. In his ASV annual address he explained that Arrindy silkworms produced cocoons of strong, coarse silk from leaves of the castor oil plant, which were less sensitive to hot winds than those of the mulberry tree which fed another silkworm. Fortunately the castor oil plant grew 'here most luxuriantly as a perfect weed' (ASV 1862: 44).

On receipt of Arrindy silkworm eggs that had become dehydrated and died during the long voyage from Calcutta, McCoy prepared 'a memorandum of instructions' for forwarding to India, and expected 'by trying the eggs, the larvae, and the pupae, to succeed in establishing the species before the next anniversary' (ASV 1862: 44). This was not to be. On 16 June 1863 McCoy reported receiving a case of dead castor oil plants with dead silkworms, and at the next meeting he handed another memo on their care and transport to be sent to Calcutta. The ASV Council mentioned these failures in its second annual report (ASV 1863), and another in its fourth annual report, which noted that McCoy had 'always been most anxious to secure the introduction of this silkworm' and had again prepared instructions for despatch to India (ASV 1866: 7).

McCoy's persistent efforts were unsuccessful, but at the annual meeting in 1871 the ASV Council thanked him for his 'great interest always shown in developing sericulture' (ASV 1871: 7). In its next annual report the ASV Council admitted the difficulty of advancing sericulture in Victoria, but remained hopeful that when white mulberry trees (widely distributed by Mueller) matured sericulture could support a viable industry (ZASV 1872).

Meanwhile there was the 'vexed question of the sparrow and minah' (ZASV 1872: 8), which had been introduced to destroy insect pests. Sparrows arrived before the birth of the ASV. Mueller (1861) recorded some in the Botanic Gardens, and ASV Council minutes and annual reports record the 1863 arrival of English, Chinese, Java and Indian sparrows, and their liberation in the Botanic Gardens, Royal Park and elsewhere.

Indian minahs (now known as Common Mynas), or mino birds as they were sometimes called, were welcomed as valuable insectivorous birds. Along with a couple of sparrows and the second lot of Cashmere goats, seven mino birds arrived from Calcutta in June 1863. They were not the first. The previous November Landells' shipment reached Melbourne. At the ASV Council meeting on 9 December 1862 McCoy heard discussion of the purchase of Landells' mino birds for the substantial sum of 20/- per head, and their despatch to the Botanic Gardens, the University and elsewhere. Mueller received 28 and McCoy six. Unable to attend the next meeting, McCoy wrote that 'the Minos liberated at the University had distinguished them-

selves as indefatigable grub and grasshopper destroyers'. They flourished in the Botanic Gardens' crowded aviary, and the following spring 50 were liberated in the Gardens (ASV 1863), where they were soon nesting in the hollows of old trees.

By 1864 the ASV had an aviary at Royal Park. At ASV Council meetings in January and February 1864, McCoy heard that, after a short stay in the aviary, 20 mino birds were liberated in Royal Park by no lesser person than the president. Later the Council reported that insect-destroying birds, including sparrows and 'a most active and interesting bird, the Indian mino, may now be considered thoroughly established, and are rapidly extending by natural means through the Colony' (ASV 1864: 33).

Indigenous and introduced birds and animals could then gain legislative protection under Victoria's game act, and the ASV was careful to have precious introduced ones, like sparrows and minahs, listed under that act. However not all Victorians were adequately impressed with their pest-destroying capacities. Complaints against their fruit-eating propensities were voiced at the ASV's annual meeting in 1868 (Balmford 1981). The meeting's report in Melbourne's *Argus* of 13 March 1868 noted that

> Professor McCoy maintained that the sparrows fed their young entirely on grubs; that the damage done to the fruit was mainly the work of native birds; and that any little fruit or grain which the sparrows might eat was insignificant compared with the service they performed in taking away the grubs.

ASV Council meetings during 1870-71, rarely attended by McCoy, considered the removal of sparrows and minahs from the protection of the game act, so that the public could legally destroy them. The ASV annual meeting in March 1871 included some discussion of sparrows, which was reported in the *Argus* and *The Australasian* (ASV 1871). The following week 'The Naturalist' column in *The Australasian* of 25 March was 'Our Acclimatised Sparrows and Minahs'. After discussing the great insect-devouring capacity of sparrows, McCoy, alias Microzoon (Whitley 1969), claimed that minahs were

> of incalculable value for checking the increase of insects which are either too large or cannot be reached by the sparrows, such as the immense variety of locusts and grasshoppers, which so swarm in some years as to destroy every green thing where they come. The insects which spend the early stages in the earth, eating the roots of the grass, &c., as the larvae of many beetles, moths, field crickets, &c. do, are destroyed in great numbers in this stage by them, and in the Royal Park and University grounds the minahs may be seen walking over the grass in regular lines digging them out all day like rooks, and when the perfect winged creatures appear, they are chased and killed by the same bird with incessant energy.

ASV opinion was less wholeheartedly supportive. Council Minutes for 19 May 1871 noted that while

> Sparrows and Minahs are extremely valuable and do great good by destroying noxious insects which otherwise would do much more injury to the fruit and grain than the birds, yet still in deference to the opinions of other public bodies the Council will not oppose [their] removal ... from the Game Act.

The ASV's annual report for 1871 noted their removal, and that 'Melbourne, from its size and importance, ought to number among its attractions a good zoological collection' (ZASV 1872: 6).

The Zoological and Acclimatisation Society of Victoria -lions and a zoo

In 1872 the Society became the Zoological and Acclimatisation Society, and *in absentia* Professor McCoy was re-elected a vice-president (ZASV 1872) – for the last time. McCoy's acclimatisation decade was ending. Sadly the ASV had not provided faunal foundations for a silk or cashmere-wool industry, and the insect-devouring capacity of sparrows and minahs had not satisfied fruitgrowers. With its name change the Society shifted its focus from acclimatisation to zoological display, and its menagerie at Royal Park changed dramatically. Now there were lions but no alpacas or Cashmere goats. The 'most notable additions' in 1872 were 'a fine pair of African lions, a leopard, a

black bear from California, and some Indian monkeys' (ZASV 1873: 7). Not one was a useful ruminant! The Zoological and Acclimatisation Society was now developing the sort of zoo preferred by a public who wanted to see more interesting animals than useful ones awaiting homes elsewhere.

Acknowledgement
Doug McCann provided Microzoon's 1871 article and evidence that McCoy was the author.

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'Sir Frederick McCoy was buried in the Brighton Cemetery, Melbourne, on May 16, 1899. As an indication of the regard in which this famous scientist is still held among natural history authorities in Victoria, the Field Naturalists Club of Victoria has undertaken, as part of its normal functions, the maintenance and care of his grave.

'The name of Sir Frederick McCoy has been commemorated in scientific circles in the McCoy Society for Field Investigation and Research, which came into existence in August 1935, a society which set out to study in a detailed manner the ecology of definite Australian environments, particularly those of the islands along the southern coastline.'

Extract from page 87,
Collections of a Century: The History of the First Hundred Years of the National Museum of Victoria,
by R.T.M. Pescott
(National Museum of Victoria: 1954).

McCoy's grave. Recently photographed by Doug McCann.

The Fate of the Cranbourne Meteorites

Sara Maroske[1]

An unknown number of years ago, a meteorite crashed to earth at what is now called Cranbourne, an eastern suburb of Melbourne. The extra-terrestrial origin of this meteorite's fragments was recognized in 1860, at which time they also became scientific curiosities considered worthy of institutional acquisition. Two men in particular vied for the right to collect them. Frederick McCoy wanted the best fragments for the recently formed National Museum of Victoria in Melbourne (hereafter Melbourne Museum), and Ferdinand Mueller (later Baron von Mueller), Government Botanist of Victoria and Director of the Melbourne Botanic Garden, thought they should go to the British Museum in London. The ensuing argument between these men involved a local and international cast of players, and their differing views of science, patriotism, and even the value of friendship itself.

Iron outcrops were known to European settlers at Cranbourne since the 1850s, but they were assumed to be of terrestrial origin. In 1860, however, Edmund FitzGibbon, the Town Clerk of Melbourne, visited the area to assess its suitability as a destination for a railway line (Walcott 1915). FitzGibbon was also something of a naturalist and he took the opportunity to examine the iron deposits. From their 'general resemblance to aerolites known to have fallen in other parts of the world', he deduced that they were the remnants of a meteorite (*Transactions of the Royal Society of Victoria* 1860). On 4 June 1860, he exhibited two specimens at a meeting of the Royal Society of Victoria, the premier local gathering of scientists, where they stirred up great interest in the members, including McCoy and Mueller.

In February 1861, a scientific expedition went to Cranbourne led by Georg Neumayer, Director of the Flagstaff Observatory and instigator of a magnetic survey of Victoria. The expedition identified a number of meteorite fragments embedded in the ground, including two large ones. The smaller of these large fragments weighed about 1.5 tonnes, and was bought from the owner of the land on which it was found by another expedition member, Augustus Abel (a German mineralogist who had settled in Ballarat). It became known as the Abel Meteorite. The larger fragment, which weighed 3.5 tonnes, was acquired by a neighbouring landowner, James Bruce (a British immigrant). It became known as the Bruce Meteorite. At the time of its discovery, this meteorite was thought to be the largest in the world (Walcott 1915; McMullen 1998; Lucas *et al.* 1994).

Neither Abel nor Bruce wanted to keep the meteorites for themselves. Abel was a mineral dealer who recognized his meteorite's value to collectors. He intended to exhibit it locally in Melbourne, then at the London International Exhibition of 1862, and offer it for sale at £300. Bruce was also happy to move his meteorite out of Australia, and decided to present it to the British Museum in London where he had 'spent many a pleasant day' in the past, 'and gained some information.' (Bruce 1862a). He apparently refused all requests to sell his meteorite, arguing that, because it was only of interest to scientists, it would be wrong to treat it as a piece of merchandise (Lucas *et al.* 1994).

The British Museum was actively involved in collecting meteorites in the 1860s, and was delighted at the prospect of acquiring the Bruce specimen by donation. It was also not averse to purchasing the Abel specimen. The Museum set about obtaining both meteorites with the assistance of Mueller. It is not absolutely clear how Mueller came to be the Museum's Melbourne agent, but he was in friendly communication with the Museum's Keeper of Mineralogy, Nevil Maskelyne (later Story-Maskelyne), as well as with Bruce and Abel, from the time that knowledge of

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the meteorites was first made public. Mueller was also on record for thinking that the specimens belonged in the British Museum, where they would be 'higher appreciated than elsewhere.' (Lucas *et al.* 1994; Mueller 1862a *unpubl.*)

The burgeoning city of Melbourne had established a natural history museum in 1854, with McCoy as Director from 1856. McCoy was aware of the interest by the British Museum in the Cranbourne meteorites and, while respecting the imperial institution's prestige, and also being in friendly communication with some of its staff, he believed that the meteorites were better placed in Melbourne. He tried to get Abel to reduce the price of his meteorite to an amount that the Melbourne Museum could afford, but was unsuccessful. He also tried to persuade Bruce to donate his meteorite to the Melbourne Museum where he argued that it would be 'of much greater interest' than at the British Museum 'from local associations' (McCoy 1862a *unpubl.*).

Bruce, Mueller and McCoy all spoke of 'interest' in the meteorites when discussing their disposal. They agreed that this 'interest' was scientific but disagreed about where it was likely to be best developed. McCoy argued that Melbourne scientists were not only well-capable of analysing the meteorites, but likely to do so with enthusiasm because of the local rarity of such objects. Mueller argued that at the British Museum they would be accessible to more scientists than in Melbourne, and therefore subject to the most capable and numerous analyses. Bruce was persuaded by both men and ended up offering McCoy half his specimen, provided the British Museum would agree to the cost of its division, and the Melbourne Museum to the cost of its transport (Lucas *et al.* 1994).

While waiting for McCoy's response to this offer, Bruce was contacted by Mueller, who asked to be given possession of the Bruce Meteorite on behalf of the British Museum. Bruce wrote to McCoy saying that he intended to accede to Mueller's request, because he assumed that 'as both Dr Mueller & yourself were members of the Royal Society [you] had mutually agreed as to the steps that each was taking in the matter.' (Bruce 1862b *unpubl.*). In this, Bruce was mistaken. Mueller and McCoy were certainly well-known to each other, and had co-operated in the exchange of natural history specimens, and in local scientific matters, without rancour, in the past (Home *et al.* 1998), but this time they had opposing views. Thus, Mueller appears to have contacted Bruce without knowing about his offer to split the meteorite.

When McCoy learned of Bruce's decision, he rallied the support of a number of local scientists and pressured Mueller to accept a division of the meteorite. Mueller felt himself torn between a desire to keep his undertaking with the British Museum to acquire the whole meteorite for its collections, and to maintain civil relations with the other members of the small community of Melbourne scientists. He believed that he was being asked to compromise his pure scientific principles by petty colonial interests, but he gave way nonetheless. In his letter of submission, he told McCoy that 'we are doing a deplorable act in cutting such a rare cabinet piece, especially as it then no longer will anywhere predominate over any other Meteors' (Mueller 1862b *unpubl.*).

On the eve of a successful (if not mutually satisfactory) resolution to the negotiations, another suggestion apparently occurred to McCoy, which he communicated to Mueller. 'As for our rival claims on the meteorite,' he declared, 'I would suggest the good old test of single combat and walking on red-hot plough shares to see with whom the right lies — unless indeed the British Museum would [solve] it by sending us Abel's own.' (McCoy 1862b *unpubl.*). McCoy seemed to be saying that he would accept a swap of the Abel for the Bruce Meteorite. This would not give the Melbourne Museum the larger meteorite, but it would give it a complete one. It would also let Mueller satisfy his obligations to the British Museum, and Mueller lost no time writing to London for agreement to the proposal.

Newspaper reports in Melbourne of the dispute between the two museums roused community interest in the fate of the meteorites. In July 1862, John O'Shanassy, the Chief Secretary (and head of the Victorian Legislative Assembly), set up a committee of inquiry to determine what, if any, action the Government should take in the matter.

The Committee was chaired by George Evans (a member of parliament) and consisted of McCoy, A.R.C. Selwyn (Director of the Geological Survey of Victoria) and R. Brough Smyth (Secretary of Mines). Mueller could hardly have been pleased with this development. All but the committee chairman were on record as supporting the view that the Bruce meteorite should not leave the colony (Lucas *et al.* 1994).

In September 1862, letters from London agreeing to the swap of meteorites were read at a meeting of the Royal Society of Victoria. Maskelyne added that the British Museum was also prepared to send the Melbourne Museum some fossil casts and duplicate specimens. He was presumably unaware that the Melbournians would take offence at his view that the swap was only assigning to the imperial and colonial museums 'their proper relative functions of mutual interest and support.' The Royal Society of Victoria scientists did not appreciate being seen as inferiors. After some discussion, they gave notice of a motion that the Melbourne Museum should keep both meteorites, and send only casts and specimens to London (*Transactions and Proceedings of the Royal Society of Victoria* 1865).

McCoy sought to garner further support for his museum's claim through the Committee of Inquiry. In 1863, after the chairman returned from a long absence from the colony, a series of committee meetings was held, and a draft report delivered to the Chief Secretary. It concluded that the Melbourne Museum had a 'right' to half the Bruce Meteorite, and the British Museum a 'right' to the other half. If, however, the British Museum had already bought the Abel Meteorite in order to swap it for the Bruce Meteorite, then the Committee recommended that the British Museum Trustees should be reimbursed the purchase price of the Abel Meteorite, and allowed to retain it for their collections 'on condition of their relinquishing all claims to the larger meteorite.' (Evans *et al.* 1863 *unpubl.*)

Mueller did not appear before any of the Committee's meetings. He waited to be called, only to discover, when it was too late for him to do anything about it, that the Committee expected him to apply to present evidence. In his absence, the Committee was free to impugn his actions and to assign their own motives to them. Its report to the Government expressed 'strong disapprobation' of 'those gentlemen who have in any way been instrumental in urging Mr Bruce to accede to the removal of the Meteorite' (a thinly veiled reference to Mueller). It also observed that Bruce had sought to be guided by the advice of 'Scientific men', and that it regretted that the advice he had received 'was not dictated by more patriotic moves.' (Evans *et al.* 1863 *unpubl.*)

In September 1863, Mueller and McCoy met at Mueller's house at the Botanic Garden and argued about the meteorites. McCoy apparently left 'in such emotion' as to prevent Mueller 'from apologising for the offence I have unconsciously given you.' Mueller tried to salvage his friendship with McCoy by offering to give up representing the interests of the British Museum (Mueller 1863a *unpubl.*). Mueller also wrote to the chairman of the now-defunct Committee of Inquiry and to Maskelyne at the British Museum in the same vein. As a public servant in the colony of Victoria, he explained that if his government chiefs disapproved of an exchange of meteorites then he would have to act in accordance with their wishes (Mueller 1863b, c *unpubl.*)

In the nineteenth century, the idea that unique natural history objects properly belong in their country of origin was novel. The primacy of imperial institutions was assumed by many colonists as well as by these institutions themselves. In making a claim for the Bruce Meteorite, the Melbourne Museum was acting out of the ordinary. Maskelyne was so irate when he learned of Mueller's treatment in Victoria that he was only just restrained, by Mueller (for the sake of the honour of the scientists of Victoria), from laying the matter before the Royal Society of London. He regarded McCoy as guilty of a 'disgraceful breach of faith', while Mueller had 'maintained an attitude such as a German — or an English — gentleman must always wish to maintain, an attitude of honour and truthfulness' (Maskelyne 1864 *unpubl.*).

What was the Government of Victoria to do? James McCulloch (O'Shanassy's suc-

cessor as Chief Secretary of Victoria in 1863) was faced with a difficult decision. He was aware that local patriots wanted the meteorites to stay in the colony, but his government was not sufficiently independent of imperial influence to disregard it entirely. McCulloch read the Committee of Inquiry's report and invited Mueller to a discussion of the other side of the argument. Mueller suggested that McCoy had failed to 'show cause why the pledge made by himself should not be redeemed' (i.e. a swap of the Abel for the Bruce Meteorite) (Mueller 1864 *unpubl.*). McCulloch agreed, and determined that the Bruce meteorite could 'be only treated as the property of the British museum' (McCulloch 1864 *unpubl.*). This decision was duly transmitted to the British Museum trustees (Lucas *et al.* 1994).

Meanwhile, McCoy was actually in possession of both meteorites. The Bruce Meteorite had been stored at the Melbourne Museum pending a decision as to its disposal, and the Abel Meteorite arrived there in late 1863. It had been addressed in London to the 'Melbourne Museum care of the Governor of Victoria', but had been delivered directly to McCoy, who did not admit to having it until pressed by the Governor. The Bruce Meteorite was removed from the Melbourne Museum in January 1865 for shipment to London. To the last, McCoy tried to stop its removal, writing letters to various government officials, but to no avail. The Bruce Meteorite was installed in the British Museum in November, minus only a thin slice which was sent back to the Melbourne Museum (Lucas *et al.* 1994).

The definitions of science, patriotism and friendship were all tested in the argument surrounding the disposal of the Cranbourne meteorites. The Melbourne and London museum directors both thought that possessing the meteorites was necessary for their proper analysis, but in the end neither institution published much about them (Lucas *et al.* 1994). The definition of patriotism was also transformed by the dispute in such a way as to admit of loyalty to colonial as well as imperial institutions. In this regard, McCoy was one of the first of many scientists who have fought for Australian ownership of significant local specimens. As to McCoy's friendship with Mueller, while it was damaged by their disagreement about the meteorites, civility, at least, between the two men was soon restored, and they continued to have a productive working relationship for the rest of their lives.

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Frederick McCoy and the Naturalist Tradition

Doug McCann[1]

Abstract
From August 1869 until May 1871, an anonymous naturalist under the pseudonym 'Microzoon' published a superb series of articles in a weekly Melbourne newspaper, *The Australasian*. The author was undoubtedly Frederick McCoy. The Microzoon articles provide a valuable early record of aspects of the natural history of Victoria, in particular the bird life, but also covering a selection of other topics including snakes, insects, fish, molluscs, geology, palaeontology and stratigraphy. (*The Victorian Naturalist* **118** (6), 2001, 309-313.)

Introduction

Frederick McCoy was one of Australia's first professional scientists. His career began in Ireland in the late 1830s – a time when natural history had gained immense public popularity and amateurs carried out a great deal of early geological, botanical and zoological work. These amateur naturalists comprised people from all walks of life but were usually from the middle and upper classes including a dedicated elite of so-called 'gentleman naturalists'. As the industrial revolution progressed, a new scientific and technological community emerged and established science as a profession in its own right. By the 1850s, this newer, younger and more numerous body of professionals were challenging and replacing the older gentlemen naturalists. Many of the older elite still held senior positions in the universities, and in amateur and professional societies, but a generational change was taking place. This succession was accompanied by a change in philosophical outlook or 'world-view' as well.

McCoy is an interesting individual for historical study because his career spans what could be called a 'paradigm shift' from amateur science to professional science, from Natural Theology to 'Naturalism' and Darwinism, and from an organic world-view to a more empiricist, mechanistic and materialistic world-view. In many ways McCoy remained true to his earlier formative influences. Henry Woodward observed, on McCoy's death in 1899, that McCoy really belonged 'to the first half of the present century, but who has survived almost to its close' (Woodward, 1899: 283). Woodward's observation is germane. True to the earlier naturalist tradition, McCoy remained an amateur in spirit even though he became a professional at a very young age.

The beginning of McCoy's career in the late 1830s represents a peak time for great collectors and great collections. When McCoy arrived in the Colony of Victoria in 1854 and subsequently established himself as Director of the National Museum of Victoria he finally had a chance to make his mark as a great collector in his own right. He spent the rest of his long career developing what became one of the great colonial museums. As a museum director and systematic taxonomist he relied upon a network of professional and amateur collectors and always remained supportive and sympathetic towards the amateur naturalist. When the Field Naturalists Club of Victoria was established in 1880, McCoy became the first President. Even though he did not attend regular meetings (see Houghton, *this issue*), McCoy was keen to encourage people of all persuasions to participate in the collection of natural objects and organisms, especially new and exotic ones, and in the study and documentation of the natural environment.

Microzoon

In the late 1860s a natural history column appeared in a weekly Melbourne newspaper, *The Australasian*, under the banner 'The Naturalist'. The author was anonymous and published under the pseudonym 'Microzoon'. It appears that it was never officially made public just who the unknown writer was, but almost a century later the naturalist D.J. Dickison speculated in the *Australian Bird Watcher* that it was probably Frederick McCoy. Dickison wrote:

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> The name and the author of the articles which ran through *The Australasian* for several years, and dealt with all branches of the natural history of Victoria, has never been disclosed. However, there is strong evidence to suggest that the writer was Professor Frederick McCoy, who was the Director of the National Museum at that time, as there is a reference in one of the old letterbooks at the museum of a proposal made by McCoy to the Editor of *The Australasian*, that he be given permission to contribute articles, at intervals, on the subjects of interest in the National Museum. It was also apparent that the articles had been written by a naturalist of some ability and who had a good general knowledge of the fauna of Victoria (Dickison, 1960: 77-78).

Dickison's claim may have gone largely unnoticed had it not been for the interest shown in the Microzoon column by the eminent naturalist Gilbert Whitley, formerly an ichthyologist at the Australian Museum. For years Whitley had wondered who Microzoon was; he had suspected that it might have been the accomplished naturalist Gerard Krefft who had lived and worked in Victoria and later became Director of the Australian Museum in Sydney, or some other competent natural history writer. After extensive inquiries Whitley became convinced that it was Frederick McCoy who was the anonymous author. In an article entitled 'Who was "Microzoon"?' in the *Australian Zoologist* in 1969 he briefly related that he thought that 'Dickison's theory was right' and published a list of all the Microzoon articles he could find in *The Australasian*. There was a total of fifty articles in all and they ran from August 1869 to May 1871.

There is no doubt that the author of the Microzoon column was indeed Frederick McCoy as Dickison and Whitley have surmised (Branagan 1998). Whitley is accurate when he states that:

> From internal evidence in the articles themselves, he was obviously a member of the Acclimatisation Society in Melbourne, on the staff of or closely connected to the National Museum, and not a young man (Whitley 1969: 121).

As Dickison observed it is obvious that Microzoon was an exceptionally competent and well-informed naturalist. He makes numerous references to the collections in the National Museum and had intimate knowledge of their content and organization. He also makes a number of allusions to the University of Melbourne where McCoy was professor of Natural Science, and to the suburb of Brighton and Brighton beach where his later home was located. In one Microzoon article (21 August 1869) the writer mentions that he was in London some twenty years previously, as was McCoy. In most of the articles the text is almost identical in style, tone and content to McCoy's writings in his official publication such as his *Prodromus of the Palaeontology of Victoria* and his *Prodromus of the Zoology of Victoria* (McCoy 1874-1982;1878-90). No other naturalist in the Colony of Victoria but McCoy would have had the detailed palaeontological, geological and zoological knowledge displayed in the Microzoon articles.

The column was one of the first natural history columns in Australia. It is a valuable early record of some aspects of the natural history of the Colony of Victoria. The articles were 'refreshingly Australian, a pioneer ornithology of Victoria, and included here and there some rare or novel species of bird or reptile' (Whitley 1969: 121). The content of the Microzoon articles is at times quite specialized and technical, mentioning such things as the appearance, dimensions, habits, location, behaviour and ecology of various natural history organisms and objects. They are also written in a relaxed and entertaining style, and are interesting and sometimes humorous. A wide range of topics are covered but there is a concentration on a detailed and systematic survey of the birds of Victoria; in fact, birds are the subject of half of the articles, making the column a valuable historical resource on Victorian ornithology. Similarly, there is a series of five articles on snakes. A random selection of other topics is covered, including fish, insects, molluscs, turtles, the Tasmanian devil, pearls and diamonds.

Of particular interest is a series of articles entitled 'Why is Australia odd?' in which the author explains how local work in Victoria by 'the Melbourne palaeontologists' (meaning McCoy and his staff) dis-

proved the popularly held notion that Australia was qualitatively different, both geologically and biologically, from the northern hemisphere, and instead confirmed that geological processes were universal and that the geological column was global. Further, the writer contended that these discoveries were fatal to the theory of 'progressive development' and the idea that evolution occurred at varying rates in different regions around the globe. According to the author those who hold such views are 'the suicidal betrayers of their own ignorance'. Instead, he suggests, the evidence does not contradict the more traditional notion of successive progressive 'creations'.

Another series of four Microzoon articles has the heading 'Geological walks and talks at large' and is a succinct and edifying introduction to field geology, including how to determine the of angle of 'dip' and the 'line of strike' of rock strata, instructions for collecting rocks in the field, and how to construct a makeshift clinometer. The author emphases the importance of fossils, stating that:

> The greatest characteristic of modern geology is the entire abandonment of the lithological character or nature of the stone as a means of identifying the various geological formations, and the firm reliance on palaeontology, or the study of fossils, alone as a sure guide (Microzoon, 25 February 1871).

The author then figuratively takes the reader for a walk from the Post Office in Elizabeth Street starting 'upon one of the most famous of all geological formations – the Silurian' the beds of which are 'sharply contorted and dipping in various directions' and walking north to Royal Park where 'in the bed of Mooney Ponds (sic) creek, and in the little cliffs on each side of it, you can learn as good a lesson on the subject as if you were in Wales' (Microzoon, 13 May 1871). The Silurian rocks held a special interest for McCoy because he had been involved in a famous debate between Adam Sedgwick and Roderick Murchison as to their structure, composition and extent (see McCann, this issue).

In the Microzoon articles there are several references to the Acclimatisation Society. The author is passionate in his defence of the principle of introducing exotic species of plants and animals and stern in his remarks against those who criticize the practice. He deplores the 'ignorant popular clamour' of those who now claim that introduced species like the sparrow are causing more harm than good:

> These birds, especially the sparrow, have multiplied greatly, and now the same outcry has arisen here as has arisen from the more ignorant of the farmers and gardeners in various parts of Europe, and in the various States of America, against useful small birds, namely, that they have been occasionally seen to eat fruit and grain in their season (Microzoon, 25 March 1871).

He argues that the sparrows consume 'enormous quantities' of harmful pest species of insects and insect larvae all year round and that the benefits greatly outweigh any relatively minor problems such as the consumption of some small part of ripened crops. As for the Indian minahs (now known as Common Mynas) the author points out that 'they are of incalculable value for checking the increase of insects' and that the value of their services are 'well known in India, and the French in New Caledonia are so eaten up by these insects, that they have asked the Acclimatisation Society of Melbourne to aid them in introducing their only help – the minah'.

One of the pleasures of perusing the column is reading the various anecdotes and poetic descriptions of the natural history of the colony. The writer employs phrases like 'this most beautiful species' (referring to Jardine's Harrier, now commonly known as the Spotted Harrier) or 'this is an amusingly pugnacious little species' (referring to the Little Whip Snake). Often he is philosophical: 'there is rarely any waste in nature', or historical: 'Even so far back as the time of Aristotle the European bird of this kind (i.e., the goatsucker) is referred to in his *History of Animals*...', or humorous: '...they are 'varra interesting' as a wise man I knew once used to say of anything he could not comprehend'. Glimpses of the interactions between the colonists and wildlife can be gleaned from the column; for example, the tiger snake is reported to be 'very common along the margins of the Yarra, especially in the Governor's grounds at Toorak, and very common in all the swampy ground near Sandridge, St.

Kilda, and other places around the city.' (Microzoon, 1 January 1870). The column is also valuable because it allows comparisons to be made between the environment and fauna of the period, particularly in the Melbourne area, and subsequent changes – for instance, the disappearance of both reedbeds and Reed Warblers from the banks of the Yarra near Princes Bridge (Microzoon, 11 February 1871), and the loss of the heathlands in the Brighton area along with their honeyeaters (Microzoon, 7 May 1870).

Occasionally the writer, when emphasizing some particular aspect of the local natural history, mentions prominent citizens of the Colony, for example, when discussing the Grey Falcon, he notes:

> A specimen of this excessively rare species flew into Captain Clarke's kitchen, at Merri Creek, after a chicken, which it carried off. It was shot, and is now in the National Museum (Microzoon, 25 September 1869).

Likewise, when discussing the Australian Goshawk:

> This fine species is rather scarce about Melbourne, but one in the National Museum was shot at Flemington by Mr. Brough Smythe, and a few others have occurred in other spots in the colony, and it is known from Tasmania to Moreton Bay (Microzoon, 6 November 1869).

Some other local identities mentioned include Professor Halford (and his experiments on curing snake bite by the injection of ammonia), naturalist Gerard Krefft, and editor of the *Argus* and founder of the Acclimatisation Society, Edward Wilson. The author even refers to himself (in the third person – as 'Professor M'Coy').

The writer's humour is evident in his discussion on the Murray Turtle *Chelymys macquaria*. Apparently the colonists did not view this turtle as a particularly attractive object for food consumption:

> ... The present species is the commonest *Cheloniax* in the Murray River, and is occasionally sent down as a curiosity to the fish-markets, with the so-called Murray cod and other fish, but it has not come into use at all for the table, notwithstanding the suggestions of the Acclimatisation Society.
>
> Mr Kinglake is often doubted by readers of his famous assertion that the present Emperor of the French turned green on a certain occasion from emotion, but I have seen the name of this creature produce exactly the same effect on a great literary luminary formerly residing in Melbourne, to whom I mentioned it in confidence at a dinner of the Acclimatisation Society, after he had incautiously swallowed a good plateful of what was called "turtle soup" on that occasion, but which I know was made of the vile anatomy of this *Chelymys*, deceitfully disguised by a skilful cook (Microzoon, 30 April 1870).

Another example of his sometimes tongue-in-cheek style is evident in his discussion of the Cicadae:

> ... This insect is a *Cicada*, nearly alike in structure, general appearance and habits, to the famous *Cicadae* of the old classic writers of Greece and Rome, who seem to have had as queer a taste in music as the modern Chinese, who, like the ancient Greeks, are said to keep these insects in cages for their song... As only the males can sing, the ancient poets attributed their loud jollity to the happiness arising from the knowledge that their wives were mute – but this is now known to be mere slander. That Tithonus, the consort of Aurora, was changed in his old age into a *Cicada*, although devoutly held by the ancients, is also now generally disbelieved by modern entomologists, who classify the *Cicada* amongst the true Hexapod insects in the modern order *Homoptera* (Microzoon, 29 January 1870).

A further example of his humour is in his discussion of the kookaburra where he refers to an account of a difficult journey by two early travellers from Western Australia, where the bird is not endemic, to the settlements of Southern Australia. The traveller's ended their narrative expressing their sense of comfort and enjoyment with which the evening passed, after due refreshment, 'listening to the laughing jackass'. The author of Microzoon noted: The German editor of a well-known geographical journal, translating this account, gives the epithet with inverted commas, and the remark in a foot-note that 'some political allusion is probably intended here, as we believe the quadruped has not been introduced into Australia.' (Microzoon, 9 April 1870).

The Microzoon series ends abruptly on 27 May 1871. The writer obviously intend-

ed to continue the series because at the end of the final article he promises to discuss the significance of asymmetrical folding of rocks such as is found in some synclines '... a fact of great importance as we shall see...'. It is not clear why the Microzoon series suddenly ended at this time; McCoy was still at the peak of his career. He went on to produce his greatest Australian publications, his *Prodromus of the Palaeontology of Victoria* (1874-82) and his *Prodromus of the Zoology of Victoria* (1878-1890). However, this was about the time that McCoy became embroiled in problems following the appointment of a Museum Board of Trustees. Whatever the reason he let the series lapse, we owe a debt to McCoy for the popular writing which he did do, and for providing us with a window into the natural history of the Colony at that particular time.

Conclusion

In 1880, a decade after the publication of the Microzoon articles, the Field Naturalists Club of Victoria was inaugurated and has continued ever since as a vehicle for studying and documenting the local natural history for amateurs and professionals alike. Considering his great pioneering contribution it was entirely appropriate that McCoy was chosen as the first President. His position was more of an honorary one than an active one; nevertheless he provided an important link between the professional work carried out at the National Museum and the more amateur work of the fledgling club.

In a more general sense McCoy represented a link between the older naturalist tradition and a newer, more impersonal, professional science. In addition, because of his considerable early experience in Ireland and England, he provided a link between a purely European view of nature and an indigenous Australian view. McCoy was moulded in the European institutions and practice but on arrival in Victoria he was confronted with a new environment. He was a major player in the attempt to Europeanise the new Colony especially through his work with the Acclimatisation Society. Nevertheless he played an important role in documenting and distinguishing characteristic similarities and differences in the natural environment between Europe and Victoria. He aided in dispelling some naive European views about the geology, palaeontology and biology of the Australian continent and helped place it in a global context. By building up large collections of the local natural history in the National Museum, and encouraging amateurs to study and collect it, he laid the foundations for further progress in understanding the indigenous natural history. It was left to others to carry that program forward from an Australian perspective, but it was McCoy who provided a bridge and a necessary first step.

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Frederick McCoy and the FNCV

Sheila Houghton[1]

Frederick McCoy was the first President of the Field Naturalists Club of Victoria, but, unlike Ferdinand von Mueller, he was not initially involved. His name does not appear in the list of members elected at the inaugural meeting in May 1880, but it heads the list following the record of the second meeting, and everyone has moved down one in the numbered sequence (FNCV Minutes 1880: 15 May 1880). The official members' register has him as number one, and it is clear from this that the position was an honorary one: McCoy did not pay a subscription (FNCV Members' Register 1880). In April 1883, at the meeting prior to the AGM, when a new President was to be elected, McCoy was elected an Honorary member, which maintained his connection with the Club, without any financial embarrassment. The invitation to McCoy to become the first President was a natural one. Not only did the fledgling Club require status, but as Professor of Natural Science at the University of Melbourne, McCoy was the obvious choice, and he was evidently ready enough to give his patronage to this new venture. Because patronage it was: in the three years of his Presidency he did not attend a single committee or ordinary monthly meeting, and played no part in the administration of the Club. His function, as he saw it, was to attend the Annual Conversazione, and deliver the Presidential address.

The Annual Conversazione was a big event in the life of the Club in the early years. It was held in the Royal Society's Hall, with a wide range of exhibits, and lectures were given, in addition to the address reviewing the year's work. (In 1896, for instance, when it was held in the Athenaeum Hall, it extended over two days.) In 1881 the Southern Science Record commented that 'it must have been a pleasing sight to the members, and especially to Professor McCoy, to see so large an audience assembled' (Anon 1881). The material for his addresses each year was supplied by the honorary secretary but something of McCoy's personality and attitude to the Club can be detected in them. His opening remarks in 1881 concentrate entirely on the 'glorious company' of honorary and corresponding members, each of whom he names, praising them for their 'enlightened zeal', 'extensive observations', activeness, or for possessing the finest collection in their particular branch of natural science. Turning to the activities of the Club he notes the papers given, mostly on botany and entomology, concluding that the evening meetings 'showed most pleasantly the advantage of men of scientific tastes and acquirements uniting together to describe the many new bearings of fresh observations'. Geology had not received its 'fair share of attention' and he proceeded to give a description of all the significant geological areas around Melbourne, comparing them to formations in England and Wales. There is a hint of astonishment in his resume of Club excursions. 'Who could have imagined that new fresh-water Polyzoa would be found in the lakes in the Botanic Gardens?' he asks. But he was glad to know that the excursions were conducted along the lines of those of the British Association, and that the 'social English recognition of the high part which the stomach plays' bringing all into 'friendly union' at the end of the day had not been neglected. His final remarks reflect the utilitarian approach to natural science, prevalent at the time, in that special attention should be given to injurious plants and insects, and he suggested that the Agricultural Association might assist the Club in these investigations (McCoy 1881).

In 1882 McCoy was unable to attend the Annual Conversazione, because he was suffering from bronchitis, which afflicted him increasingly in his later years. Rev. J.J. Halley read the speech in his absence.

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The FNCV had every appearance of becoming an established institution, but the majority of its most active members were still amateurs, and there is a hint of condescension in McCoy's opening remarks that they were meeting again 'to celebrate our usual annual "commencement", as the University men say...' The 140 ordinary members included ' nearly all the best known Victorian lovers of Nature' and he acknowledged the value of 'out-of-door exercise ... its great healthy attraction and its peculiar usefulness'. He noted again that amongst the Honorary members were 'the most distinguished Naturalists in every department of Natural Science in this and the other Australian colonies.' There was no doubt that there was a place for the Club, since nothing could be more really useful to Science than genuine field observations, accurately recorded, and he suggested that the 'interchange of observations and experiences of the collectors' (which had been the motivation for the establishment of the Club in the first place) should be 'recorded in a kind of commonplace book', which would make a 'delightful volume which would be eagerly read both here and at home'. In due course the Club produced *The Victorian Naturalist*. He praised the Club's plans to offer prizes to State school children for collections, with accompanying papers, at the next Annual Conversazione, and compared this to the practice of Professor Henslow ('my old friend') in his parish in Suffolk, England, who had observed the influence for good of such occupations on character and habits of later life, on the children of both sexes. McCoy's address concluded with practical instruction on how specimens should be recorded, especially if the name was not known (a numbering system), and suggestions of areas of study (McCoy 1882).

By 1883, in his third address, McCoy was obviously fully convinced of the usefulness of the Club, and approved of the direction it was taking. He regretted that it had not been possible to give prizes to State school children, owing to lack of funds, but expressed the hope that the government might make a small grant for this purpose. Excursions were now being run under the leadership of a competent person, which gave 'definite character to the work of each excursion' and less time was wasted in 'desultory wanderings'! McCoy, of course, had no direct experience of Club excursions. He praised the practice of cooperation between the amateur making local observations and someone with expert knowledge of the subject, as typified by Dudley Best's work on Colonel T.B. Hutton's collection of beetles from the Dandenong area. The study of ants was 'essentially one for a field naturalists' club', and he considered A.J. Campbell's admirable paper on Victorian birds' eggs 'a perfect model of the sort of continued, careful observation and record of facts which would render this Club famous'. If the FNCV had not quite arrived, it was well on its way. Scientific acknowledgement had been given to the 'acute observer'. J.F. Bailey, who had followed up McCoy's observations on fossil ear-bones of whales from the Waurn Ponds Miocene tertiary quarries by discovering similar remains near Cheltenham, recognised a new species which McCoy had named *Cetotolithes baileyi* in his honour (but unfortunately had been unable to illustrate or describe it because the Mines Department had ceased publication of the *Palaeontological Decades*). Henry Watts had collected and mounted many *Anoplura* (sucking lice) of Victorian birds, which were now in the National Museum. McCoy's attitude here was very much, 'keep up the good work', and he put forward suggestions for further study: fungi, to be sketched and coloured in the field, being a 'subject ... of great interest as not to be ascertained in the closet'; spiders; the teeth on the tongue of each species of the Gastropoda (suggested the previous year, but not followed up); insect larvae; living Polyzoa, Victoria being particularly rich in 'these beautiful little objects'; Hydroida; mosquitoes (those in Tasmania had been well described); and ants and gadflies. He concluded with a comment characteristic of his time, that all these subjects would provide valuable information which would be welcomed 'at home' (McCoy 1883).

McCoy's term of office came to an end in 1883, and Dr F.S. Dobson, M.L.A. was elected in June. He chaired the next committee meeting, and a subsequent special

meeting, at which he moved a motion to repeal Rule 8, which said that the President should retire annually, and not be eligible for re-election after the second year. This motion was carried by 'a large majority' (FNCV Minutes 1880: 11 June 1883). Dobson's expressed purpose was to clear the way for McCoy to reassume the presidency (Dobson 1883). He then resigned, but this political manoeuvre did not work. It would seem that McCoy was not approached after the June meeting, because in September Dobson wrote to the committee asking that some action be taken on his letter of 6 July resigning his position. The committee decided that Dobson, J.F. Bailey and T.A.F. Leith should wait upon McCoy (FNCV Minutes 1880: 1 October 1883). A month later Bailey and Leith had not interviewed Dobson about the matter (FNCV Minutes 1880: 5 November 1883). Was it that they felt the situation was too delicate, or did the committee not really want McCoy back again? In December the secretary was directed to write to McCoy requesting him to name a place and time to discuss the matter (FNCV Minutes 1883: 3 December 1883). McCoy replied, explaining that while University duties had prevented him from making an appointment, he was referring to previous communications expressing objections to his reassuming the Presidency, which he found unanswerable, so while thanking the committee for thinking of him, he felt bound respectfully to decline (McCoy 1884a). There are several oddities about this. McCoy said that he thought the objections came from Dr Lucas. The 'previous communications' may refer back to 1881, when Lucas had proposed the alteration to Rule 8, limiting the tenure of the president to two years. The other part of the motion related to the Vice-Presidents, ruling that one of them should retire each year in rotation and not be eligible for re-election. This affected Lucas himself, but he had already retired from his position at the end of the first year in May. Lucas's motion was carried (FNCV Minutes 1880: 8 August 1881). McCoy would have been informed of this amendment, perhaps in the normal course of things, or because he would be directly affected at the end of the Club year in 1882, but the alteration was then presumably forgotten, or ignored, and McCoy was re-elected for a third term. It is likely that Lucas voiced his objection, but if so, there is no record of it. After the annual election in 1883 he was no longer a committee member, and although he was present at the special meeting when Rule 8 was repealed, he was not reported as taking part in the discussion.

Whether Thomas Lucas was motivated by personal reasons, or a desire to have things done in what he considered a right and proper manner, is unknown. He had had experience of field naturalists' clubs in England, where office-bearers may have been regularly replaced, or he may have felt that the Club would benefit by having a change to someone who would play a more direct part in its administration and activities. There may have been a philosophical antagonism between the two men, though there is very little evidence to support this. McCoy was staunchly opposed to Darwin's theory of evolution, while Lucas had grown up in an atmosphere of enquiry, with a father who was a Methodist minister and also a geologist, who gave a public lecture on 'Geology and Genesis' in which he attempted to reconcile the biblical account of the creation with history as read by the geologists (Lucas 1937). Lucas's published articles do not make clear what his views were. Perhaps he kept an open mind on the subject, but both he and McCoy were geologists, which could have provided matter for argument, especially in the climate of the times.

They were certainly opposed in their approach to natural science. McCoy had made his name by the prodigious amount of work he did in classifying the great collection of British fossils in the Woodwardian Museum, in Cambridge, which 'astonished' his collaborator, Adam Sedgwick, who wrote of 'this excellent naturalist', 'incomparable and most philosophical palaeontologist', the subsequent publication of the description of the collection, and an enormous number of articles in learned journals. McCoy was essentially 'a naturalist who worked indoors' (Fendley 1974). C.A. Topp, a member of the Club and a later President, who had been one of McCoy's students, said of McCoy that 'the

only flowers exhibited in his lectures were the flowers of rhetoric' (Lucas 1937), while students in the 1880s complained that there were no geology excursions (Fendley 1974). Lucas, in addition to his geological interests, was an enthusiastic entomologist and ornithologist, who liked nothing better than to get out in the bush. His writings, couched in a flowery, exuberant style, reveal a sensuous as well as a scientific approach to nature.

McCoy was impetuous and quarrelsome (Blainey 1957). Lucas would also appear to have been intemperate (a not unusual effect of tuberculosis). A curious incident occurred at the Club's monthly meeting in January 1881. F.J. Williams had been elected at the first meeting of the Club, and was one of the 'original members'. In August 1880 he had written to the Club offering his services in procuring and preparing specimens of birds and animals (Williams 1880), and he enclosed a testimonial from McCoy who said that Williams had done this for the National Museum of Victoria, and that he was a 'most trustworthy and respectable man as well as a good bushman' (McCoy 1878). At the Club meeting Dudley Best read Williams' paper on the Marsupials of Australia. The record of the meeting said, rather dismissively, that 'although the writer added nothing new to what is already known of these animals, he had evidently carefully studied the subject' (FNCV Minutes 1880: 10 January 1881). Williams was in the audience, and was highly offended at the reception given to his paper. He wrote a letter to the committee protesting that the chairman (Lucas) had made 'some very disparaging personal remarks', about him and his orthography, but added that it was no more than was to be expected from a person who 'from the very first of this Club' had spoken 'most disrespectfully of Professor McCoy'. Williams then made some very disparaging remarks about Lucas, whom he considered to be 'somewhat proficient in dealing with sick and fancy Dogs' (Williams 1881)! Obviously several people's 'sensibilities' were touched on this occasion, but it does indicate that Lucas had some antipathy towards McCoy.

With McCoy declining the presidency, the committee asked Dobson if he would see out his term, which he did, and he gave the annual address in 1884. He wrote to McCoy to ask for advice on the direction which the Club's energies should take in the coming year (Dobson 1884). McCoy suggested a study of insects which were injurious to plants, both native and introduced, and in particular whether any of them were attacking imported plants in place of their native food. A study of galls would be equally useful, little having been done in this country (McCoy 1884c). The committee again approached McCoy to become President in 1884, after Mueller had refused the position, but again McCoy declined (McCoy 1884b).

Members of the Club found the National Museum a great resource. In March 1883 a visit was included in the programme, McCoy having 'expressed his willingness to personally receive such a visit' (FNCV Minutes 1880: 5 March 1883). Two years later, however, they were not so happy about the institution, and a deputation consisting of T.A.F. Leith, Dudley Best, Henry Watts and F.G.A. Barnard handed to the Trustees of the National Museum a statement of 'the most pressing reforms needed' (FNCV Minutes 1883: 2 March 1885). This was passed on to McCoy as Director, to which he duly replied. Lack of money and lack of space were the reasons for inadequate staff and the smallness of the library (though most of the works of reference were available in the Public Library). McCoy pointed out that the Sydney Museum had a staff of seventeen at a cost of £2,833 , while there were only eight staff in Melbourne at a cost of £1,230. £50 to £60 a year was available for the purchase of periodicals and books, compared to £500 in Sydney. He was 'astounded' at the criticism that all the specimens were not displayed and that Victorian entomology and oology were unrepresented. The finest collection of Victorian Entomology in the world was held in the museum, he said, adding that 'prominent members of the Field Naturalists Club' had been classifying their specimens from it for years. The collection of Oology was 'as perfect as I have been able to make it'. As to the suggestion that

'the nomenclature and classification should be brought up to the most recent determination' McCoy responded indignantly that no museum in the world could maintain this standard, but he felt sure that the National Museum came as near to this 'point of perfection' as any other great museum, and that it was his 'delight' to continually update the classification. In view of the amount of work involved, and the lack of assistants, this criticism does seem somewhat unjust. The collection of conchology (specifically mentioned in the submission) was the finest in the world, and the ornithological collection approached this. As to the final request that the *Prodromus of Zoology* appear more frequently, that was out of his hands, and the responsibility of the Government Printer, who had only one lithographic press-man (McCoy 1885).

In 1886 Mueller, who had declined the presidency of the Club five times, suggested to the committee that they make McCoy and himself patrons of the Club, thus representing 'the two great branches of animated natural history' (Mueller 1886). McCoy declined, or failed to reply, perhaps offended by the criticisms of the National Museum in the previous year (Taylor 1996). In 1889 they elected him to serve alongside Mueller, and McCoy wrote thanking them for 'the high compliment' (McCoy 1889). Any ruffled feelings over the museum were in the past, and Thomas Lucas had moved to Queensland for his health.

Whatever the relations between McCoy and the FNCV may have been from time to time, the Club did not fail to congratulate him when the occasion demanded. In 1883 they congratulated him on being awarded a Diploma of Honour at the Amsterdam Exhibition (FNCV Minutes 1880: 10 September 1883), and again in 1891 when he was knighted. There was some reflected glory for the Club on the latter occasion, Baldwin Spencer pointing out that there were only six or seven 'biological knights' and the FNCV had two of them in their patrons (Anon 1891). In 1946 the Club, together with the Royal Society of Victoria and the McCoy Society, renovated the memorial to McCoy in the Brighton cemetery, and on 1 June there was a ceremonial planting of native shrubs (FNCV 1946).

McCoy's last function in connection with the Club was his attendance at the 1896 conversazione, when he proposed a vote of thanks to his fellow patron, Mueller, for his inaugural speech (Anon 1896). He referred to the great help which field observers could be to the scientific specialist, a theme which he had pursued from the days of his Presidency.

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Frederick McCoy's Mount Macedon Property

Doug McCann[1]

Abstract
In the later part of his life Frederick McCoy selected and developed a bush block on the slopes of Mount Macedon. The conditions for purchase required him to plant and foster the growth of various northern hemisphere trees and shrubs. He duly cleared part of the block, planted trees, shrubs and grass, put up fencing, constructed a small reservoir and laid pipes. In 1876, having fulfilled government requirements, he purchased the property and retained ownership until 1890. (*The Victorian Naturalist* **118** (6), 2001, 319-321.)

Introduction

When Frederick McCoy first arrived in Melbourne in 1854 his living quarters in the grounds of the new University of Melbourne were not yet finished but upon completion he took up permanent residence. He lived on campus for a number of years then moved to his house 'Maritima' at Brighton (Brighton Beach) where he resided until his death on 13 May 1899. It is little known, and has not been previously noted in the biographical literature on McCoy, that he also owned a large bush block on the slopes of Mount Macedon.

Documents from the Department of Lands and Survey show that McCoy in 1874 selected land on the eastern slope of Mount Macedon which previously had been State Forest. The location was just north of what is now the township of Mount Macedon. The property covered two lots with a total area of 'sixteen acres five roods and thirty nine perches more or less being allotments three and four of Section five in the parish of Macedon County of Bourke'. Since the area was more than ten acres, a special licence was required for occupancy, which was granted on the condition that he improve the site and 'plant upon each and every acre of land hereunder at least ten (10) useful timber trees of the following kinds viz. *Cedrus Deodora* (sic), pines of all kinds and *Wellingtonia Gigantea* (sic) and shall foster the growth of such trees in accordance with any code of instructions that may be promulgated by the Board of Land and Works'. The reason that he had applied for a larger acreage, McCoy revealed, was 'to enable me to irrigate the plantations by bringing the water in pipes from the creek above the bridge'.

McCoy conscientiously went ahead with the obligatory 'improvements' such as clearing trees and scrub, planting new trees and fencing the property. In 1876 he submitted a schedule of improvements and associated costs, along with a request that the land be put up for sale by auction. The request was granted and McCoy purchased the land. Among the improvements he claimed to have carried out included planting '160 well-established 8 years old *Pinus insignis*'. Another improvement mentioned under the subheading 'Fencing', included the erection of ten chains of three-rail fences and forty chains of picket fences. Under the subheading 'Clearing etc', McCoy indicated that he:

> Paid Alfred Turner for tools, posts and rails and pickets, and labouring wages, and superintending their work of felling and grubbing trees, cutting up and burning fallen timber, cutting ferns and scrub, ploughing, harrowing and sowing with grass seed, carting off stones, putting up fencing etc.

Included on his list of improvements and expenses were:

> Two and a half years travelling, personal and miscellaneous expenses incurred in supervising and directing the various works on ground, laying out paths, marking foundations, taking levels for bringing down water supply etc etc.

The Reservoir

One of the most interesting items listed in the documents quoted above is the reference to provision of a water supply. McCoy supervised the construction of a small reservoir in a well-elevated position just above and towards the eastern side of

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the property to store and divert water from the Turitable Creek so that there would be a reliable irrigation source for his newly established northern hemisphere plants. The Turitable Creek is a small stream with a steep gradient that has its origin further up the mountain and winds downhill to form the western boundary of the block. This moderate capacity, but neatly built, reservoir still exists, along with some of the original earthenware pipes, although everything is now largely silted up. The reservoir itself is skilfully constructed from local stone with perfect formwork to create walls and spillway. The stone used (probably dacite) was capably crafted and precisely assembled to provide a functional dam and a dependable water supply that McCoy and his exotic plants would have found welcome, especially during the harsh Australian summer.

Projecting from the lower part of the dam wall is an earthenware pipe with a valve which, when closed, allows the reservoir to fill and divert water to the western side of the dam to an underground pipeline outlet with a second valve to regulate flow. The pipes are approximately ten inches in diameter and the buried pipeline runs downhill to the lower parts of McCoy's original block. Water was piped down from the reservoir to supply water for the recently planted trees and shrubs, many of which are still extant.

The trees

One tree that was almost certainly planted by McCoy is a California Redwood *Sequoiadendron gigantea*. One can only speculate, but the Sequoia was probably acquired through the agency of Ferdinand von Mueller. Other trees of a similar vintage, and therefore probably also planted by McCoy, include English Oak, White Oak, Negrohead Beech *Nothofagus moorei* and Rhododendron. There is also another slightly younger group of trees that have been estimated, by a later owner of the block, Reg Hume, to be in excess of 100 years old, and may also have been McCoy's handiwork, but these are less certain. These include trees such as English Maple, English Beech, Sweet Chestnut, Horizontal Elm and Variegated Holly. There are many other trees and shrubs which are much younger and were planted after McCoy's time.

As well as the exotic trees and shrubs there is also a great deal of native vegetation, particularly towards the back of the property adjoining the Turitable Creek. The natives include Messmate *Eucalyptus obliqua*, Manna Gum *E. viminalis*, acacias such as Silver Wattle *Acacia dealbata*, Blackwood *A. melanoxylon*, Prickly Moses *A. verticillata*, a distinctive heavy understorey of Hazel Pomaderris *Pomaderris aspera* and various other shrubs, ferns and fungi. Altogether there is a pleasing blend of northern hemisphere trees and native vegetation. McCoy, in his earlier years in the Colony of Victoria, was an enthusiastic advocate for the introduction of european (especially English) plants and animals. He was a former president of the Acclimatisation Society (see Gillbank *this issue*). He would have been proud of his achievement in taming and 'beautifying' the wilds of Mount Macedon (although many of his introduced species are now invading native forest).

Concluding remarks

As McCoy indicated in the documents cited above, he commuted from Melbourne to his Macedon bush block, at least during the first couple of years when he was instituting his improvements. So far nothing has been found to suggest that McCoy and his family ever lived there or constructed a dwelling, temporary or otherwise. He retained ownership of the land until 1890. For many privileged nineteenth century Victorians like McCoy the idea of owning a mountain property where one could escape the city and enjoy the coolness and shade of a fern gully beside a gently flowing creek was an attractive proposition. Possibly, at this stage of his life, he used the property purely for recreational purposes but it is also probable that, being the uncompromising and irrepressible naturalist that he was, he treated it as his own private field study area as well as a recreational venture.

The current name of the property is 'Cooinda' but again there is nothing to indicate whether it was McCoy or a later owner who gave it this title. Several eminent Victorians since McCoy have owned

the property, including Sir Edward and Lady Eliza Mitchell, who purchased it in 1902, and Reg and Margaret Hume, who purchased it in 1964. Reg Hume built a new home, planted many new trees and shrubs, and arranged for tree surgery to save some of the older trees that had been affected by fire or disease. Some of the older trees were lost in the Ash Wednesday fires in 1983 and Reg Hume applied himself with great devotion and energy to restore and save those that he could. Several subdivisions of the block have taken place but there is still a large section of the original that remains intact. The property was, and remains in part, a memorial to Frederick McCoy's love of northern hemisphere trees.

Acknowledgements

Thanks to Reg Hume for providing primary documents, Neil and Francis Courtney for providing an account from which this paper was written, Adam Warden for permission to visit Cooinda, Bernie Mace, David Ashton and Anthea Fleming for helpful comments.

The History of the McCoy Society

David H. Ashton[1]

Introduction

In 1935 Raymond Priestley, the Vice Chancellor of Melbourne University, suggested that a Society for the Study of Field Investigation and Research be set up and on 9 July of that year the first meeting was duly held in the Zoology School. The name was changed later to the McCoy Society in honour of the first professor of Natural Science at Melbourne University in 1854. McCoy's specialty was geology and his interests were broad, such that he made demands for and obtained a museum for the University and a Botanic Garden.

The inaugural meeting was held in the Zoology School on 10 August with Professor Wood Jones of the Anatomy Department as president. Notable members of the Melbourne University Departments of Botany, Zoology and Geology were present, as well as many other interested people outside the University, such as medics and school teachers. Professor Wood Jones was the driving force and soon garnered sufficient funds to purchase camping equipment including the great marquee, tents, trestle tables, cooking gear and 'thunder boxes'. At that time, membership was limited to 50 and many famous names headed the list, such as Professor Oscar Tiegs, Dr Reuben Patton, Miss Maisie Fawcett, Dr Gwyneth Buchanan, and Associate Professor Fred Singleton. Professor Wood Jones was of the opinion that islands made the best venues for study since they were easily definable, somewhat inaccessible and intrinsically interesting in terms of their formation, their biota, species dispersal and general ecology. Work needed to be clearly focussed, and being multi-disciplinary, was stimulating and useful to the advancement of Australian Science. Whenever land-based projects were undertaken however, they became open-ended and too big to complete.

The activity of the Society can be divided roughly into four general phases:

A. Island expeditions 1930s;
B. War-time excursions 1940s;
C. Land-based projects 1950s;
D. Return to island expeditions 1960s, 1990s.

Without doubt the recruitment of undergraduates and postgraduates contributed to the momentum of and interest in the Society. It had a dynamic population with senior staff of university departments maintaining the continuity.

In the early years field work was something of a novelty and the strength of the Society lay in the interaction of a number of disciplines. In later years field work in many departments became more common and the incentive to work collectively

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diminished as other competing commitments developed. After 1970 general interest faded away and moreover, the National Australia Bank continued to complain about the Society's 'moribund account'. Therefore in 1992, as the last president and committee member, I resolved to complete the McCoy Society's contributions by a study of Pelican Island in Western Port, along much the same lines as the initial study on Lady Julia Percy Island. Following several years' work the results were published, the McCoy account was closed down and the residue of funds donated to the library of the Royal Society of Victoria.

The following account is compiled from my own recollections and photographs as well as those of various members of the Society. Much material was also gleaned from letters and minutes and photographs stored in the Archives of the University of Melbourne.

A. Island expeditions – the pre-war years, 1935-1939

Camping expeditions to islands off the south east Australian coast were mounted every long vacation over these years.

1. Lady Julia Percy Island, 1935-1936

This was an intrepid expedition lasting two months in summer 1935-36. It set off from Port Fairy after a rousing civic reception by the mayor of Port Fairy and the Secretary of the Progress Association. After a rough 19 km boat trip stores were landed from a dinghy and hauled up 30 m cliffs to the camp site on the exposed, flat-topped, basalt terrain.

The island was surveyed and geology, botany, zoology studied, together with some pioneering work on soil bacteriology (Fig. 1). Vegetation was relatively simple and consisted mainly of grassland, bracken fernland, and near the shoreline, succulent herbfield. Of interest were the large colonies of fairy penguins, mutton birds and Australian fur seals. Rabbits, introduced in 1868, were present in plague proportions. The work was published in the 1938 *Proceedings of the Royal Society of Victoria.*

The island was visited by a group of naturalists in 1965 and again two years later after a very severe drought (Pescott 1965, 1968). The plant communities were generally similar to those three decades earlier although severe damage was caused by the drought. Rabbit numbers had been reduced in 1965, presumably by myxomatosis, but by 1967 they had increased enormously and were now starving. Grasses were decimated and succulents severely grazed. Over the period of 27 years the number of vascular plant species had increased from 32 to 84 and the contribution of alien species increased from 12 to 45%. The

Fig. 1. Members of the McCoy Society on the first expedition to Lady Julia Percy Island, 1935-36. Centre, Irene Dewhurst; extreme right, Associate Professor Fred Singleton. Other names not known.

diversity of birds recorded was generally similar and eight of the major species were common to both studies.

As pointed out by Dr Sophie C. Ducker, a tapestry by the wife of one of the members of the original expedition, Eugenie La Gerche, depicting a map of the plant communities of Lady Julia Percy Island, at present hangs in the office of the Dean of Science at Melbourne University.

2. Sir Joseph Banks Islands off Port Lincoln, 1936-37

This was a major and expensive expedition which lasted two months and coincided with South Australia's Centenary celebrations. It concentrated on two Islands of the group, Reevsby and Kirkby Islands, both of which were of low relief and consisted of calcarenite over a granitic base. In this relatively dry environment vegetation consisted of coastal grasses and scrub (e.g. *Atriplex paludosa*, *Olearia axillaris*), with an almost total lack of trees. The botany of the islands was described and detailed studies made on marine communities as well as birds, reptiles, seals and penguins. The combined work, again under the leadership of Professor Wood Jones, was published in the *Proceedings of the Royal Society of Victoria* in 1939.

3. King Island, Bass Strait, 1937-38

This expedition involved many well-known zoologists (Professor Buchanan, Charles Birch, George Wade, Jim Guest) as well as botanists and geologists. Studies were made in wet sclerophyll forest where the East Gippsland Olive Berry *Elaeocarpus reticulatus* occurs. The Tasmanian Celery-top Pine *Phyllocladus aspleniifolia* was present before numerous destructive fires. Marine algae were collected and reptiles, insects, frogs and birds were studied in the reed swamps and marshes. The onset of World War 2 prevented any of this work from being published.

4. Sunday Island, Corner Inlet, 1938-39

This island provided an opportunity to assess the concepts of plant succession in a coastal sand dune environment. It was led by the new, young Professor of Botany, J.S. Turner, in the severe drought and fire-prone summer of 1938-39. The camp was based on a deserted house of the early pastoralists. After the war, a follow-up expedition took place in February 1947 with botanists, zoologists and geographers. The input of Dr Eric Bird in the late 50s provided a great impetus for the completion of this work on the role of geomorphology and soil formation in the succession of plant communities from grassland of the foredunes to sclerophyll woodlands of *Eucalyptus viminalis* and *Banksia serrata* in the hinterland. It was finally published by Turner, Carr and Bird in the *Proceedings of the Royal Society of Victoria* in 1962.

B. The War Years, the 1940s

1. Walpeup Research Station, 1943

A group travelled by train to Walpeup and obtained enough petrol coupons to undertake trips to the Pine-Belar and Mallee communities nearby as well as the Pink Lakes and the sand hill country to the south. Vegetation, bird life and entomology were studied but not written up.

2. Cathedral Range, Buxton, 1947

A camp was set up beside the Little River which allowed access to wet forest (*E. viminalis*) in the valley and dry stringybark forest (*E. macrorhyncha*) on the sandstone range. Of interest was the patch of dwarfed Snow Gum *E. niphophila* on the Sugarloaf at 610 m. The area was diverse, the roads atrocious and the camp rendered exciting by the visitation one night of local yahoos intent on cutting tent ropes. Needless to say they were repelled with some vigour by one of the members (Neville Walters), brandishing his ghurka knife. This trip was my introduction to the Society as a student about to start third year science.

3. The Black Range, Grampians 1948-49

This camping expedition involved many University botanists, zoologists and geologists – staff, postgraduates and undergraduates. The camp was set up at Cherrypool – a corruption of the Aboriginal 'Cherapol' meaning big water (Fig. 2). One seasoned field geologist, Peter Crohn, was heard to say 'the first one in for a swim gets all the leeches'. Mercifully in that long hot summer there were none. Vegetation was related to soils and geomorpholgy and ranged from stringybark (*E. obliqua*), sclerophyll woodlands (*E. baxteri*), cypress pine (*Callitris rhomboidea*) on the sandstone

Fig. 2. McCoy Society camp at Cherrypool, the Black Range, Grampians, 1948.

range to grassy woodlands of Yellow Gum *E. leucoxylon* and Red Gum *E. camaldulensis* on the adjacent plains. A follow-up trip took place in 1949 but difficulties with bogged vehicles took the edge off the enthusiasm. The project became too big and open-ended and finally lapsed.

C. Land-based expeditions of the 1950s (apart from Phillip Island)

These varied from the Western District to Wilson's Promontory.

1. The Rhyll Salt Marshes, Phillip Island, 1950

This was a short excursion to study the communities of the salt marsh and mangroves under the leadership of Kingsley Rowan. It involved studies of point quadrat quantitative ecology by the brilliant Dr David Goodall.

2. Lake Purrumbeete, Camperdown, 1951-54

Maisie Fawcett encouraged a study of the limnology of this lake where quinnet salmon had shown very impressive growth rates. The first camping expedition was based at the Fisherman's Reserve in summer 1951 during which the prevalence of tiger snakes caused a great deal of excitement. The shoreline and tall submerged aquatic vegetation was mapped, bird populations assessed, and the geology of the maar and surrounding tuff deposits investigated as well as the chemistry of the lake. Subsequent trips in 1952 and 1954 were based on Manifold's property and a small shed was built to store equipment. A boat was used to sample the lake environment and algal plankton such as *Microcystis*. The work clearly demonstrated the existence of a thermocline in summer and its absence in winter. Data was gathered on oxygen levels using methylene blue titrations. However, once again the project became too large and open-ended and other research work competed for time that could be devoted to it. The study lapsed and this pioneering work was taken up by other research workers in later years.

3. Excursion to Chinaman's Island, Warneet, 1957

This was a day excursion to reconnoitre the heathy manna gum woodland and the surrounding mangroves, some of which were anchored in the lateritic rock of the shore platform.

4. Waterloo Bay, Wilson's Promontory, 1958

The was a fairly large expedition, most arriving by boat from Port Welshpool – the small group who trekked in later by land with the perishable supplies lost the track and spent a memorable night in the bush. The work was mainly reconnaissance involving botanists, zoologists and geologists.

5. Mt Hunter Peninsula, Wilson's Promontory, 1959-63

This was undertaken with some enthusiasm and provided a venue to study vegetation which had escaped the disastrous fires of 1951. The camp was set up near Lawson's Creek after the group was forced by low tide to carry gear some hundreds of metres, being harried all the while by hordes of voracious march flies. The geology and geomorphology was studied, including the old tin mine site, granitic features, hillwash deposits and sand dunes. The area was surveyed and plant communities mapped as heath, wet and dry sclerophyll forest (*E. obliqua*), sclerophyll woodland (*Banksia serrata*), coastal scrub, swamp and fern gully, the latter being dominated by columns of climbing fern (*Gleichenia microphylla*) along Lawson's Creek. Of considerable interest was the series of beach ridges and dunes at Entrance Point, which showed both the build-up and truncation of dunes as well as soil podzolization consistent with a successional interpretation. Nutrient-rich dune slacks were dominated by mesophytic fen vegetation of *Sium latifolia*, *Urtica incisa*, *Typha latifolia* and *Phragmites australis* which contrasted with the sclerophyllous and sedge-dominated, acid brown swamps on granite to the south. Mt Hunter vegetation demonstrated a dramatic effect of aspect and exposure with the occurrence of heath on the north face, tall *E. obliqua* forest on the south, and fern-rich (*Gleichenia dicarpa*) heath reminiscent of Tasmania on the eastern and southern spurs. *Australina pusilla* var. *muelleri* occurred in the fern gully on Mount Hunter, whereas in other areas of the Promontory it is replaced by *A. pusilla* var. *pusilla*, as in wet forests of Tasmania. The heath and sclerophyll woodlands showed abundant evidence of invasion by coast tea-tree, similar to other areas on the Promontory.

In March 1962 the whole area was razed by a wildfire burning north from Mount Margaret. The camping site was revisited the next year and the vegetation regeneration assessed (Fig. 3). The fine layers of powdered charcoal pervaded all clothing, equipment and skin. The density of Coast Tea Tree *L. laevigatum* regeneration was calculated to be of the order of 12 million seedlings per hectare, vying in size and density with the capsules of the fire moss, *Funaria hygrometrica*. This area was monitored over the ensuing 12 years and results included in a manuscript on sand dune ecology on Wilson's Promontory at present under review. The general project however, became large and difficult to sustain and unfortunately was not written up for publication.

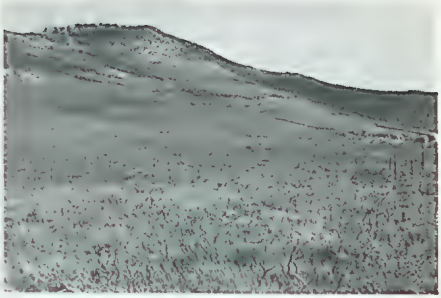

Fig. 3. Heath plateau (burnt out grassy aspect), Mt Hunter, heath to west, tall dry sclerophyll forest to east.

D. Return to island ecological research 1960s, 1990s

These involved camping expeditions to the Bass Strait islands and repeated day excursions to Western Port.

1. Hogan Island, 1968

This expedition was undertaken from Port Welshpool for two weeks in January 1968. Most work was done on Hogan Island (Fig. 4) but short trips were made to nearby islands – Long, East, Round and Twin Islands. Vegetation communities were mapped on granite and calcarenite. A small peaty soak provided material for pollen analysis down to a depth of 70 cm. Vegetation was predominantly tussock grassland (*Poa poiformis*, *Stipa teretifolia*), low shrubland (*Marrubium vulgare*), succulent herbfield (*Disphyma australe*) and remnant paperbark (*Melaleuca ericifolia*). There was abundant evidence of human interference through burning and grazing activity, rare shrubby areas occurring only in protected rocky niches. The results of pollen analysis by Geoff Hope suggested that the increase in weedy species (*Rumex*, *Marrubium* and probably *Hypochoeris*) was commensurate with pas-

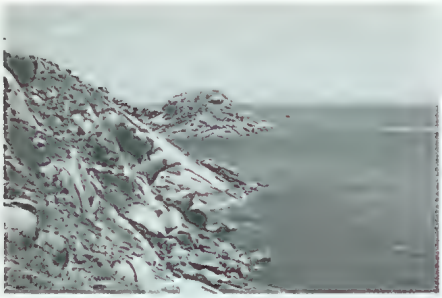

Fig. 4. East coast at Hogan Island, 1968.

toral activities post-1835. Various aspects of the research were published in 1974 in the *Papers and Proceedings of the Royal Society of Tasmania*, because being Tasmanian territory it was deemed unsuitable at that time for the Victorian *Proceedings*.

2. Curtis Island, 1971

This expedition was initiated by Dr Jack Massey of the Geography Department, Melbourne University. Landing was effected on the rugged coast with considerable difficulty and skill. The island, rising to 350 m, was more varied than Hogan Island and probably received more rainfall. Soils were skeletal and vegetation consisted of tussock grassland, areas of *Melaleuca armillaris* scrub and succulent coastal herbfield. This scrub was the western limit of this species from the east coast of Australia. Other species (*Ixiolaena supina* and *Albizzia lophantha*) provided links with islands off the Western Australian coast. This research was also published in the Tasmanian *Proceedings* in 1974, and included work of an ancillary trip by Dr Jamie Kirkpatrick on Rodondo Island.

3. Pelican Island, Western Port, 1992-98

This intriguing but very small island had been frequently observed from the Corinella-French Island punt and assumed to be salt marsh and paper bark. It was decided in the late 80s that it might make a good venue for a last expedition of the McCoy Society. The initial trip by fishing boat in 1992 involved a large contingent from the Melbourne University Botany School, who surveyed the vegetation, soils and geomorphology of the island. Rocky salt marsh on the basaltic shore platform was backed by tussock grass (*Poa poiformis* and *Stipa teretifolia*) which surrounded open, somewhat decadent scrub of Blackwood *Acacia melanoxylon*, *Lavatera arborea* and *Clematis microphylla*. Weedy grasses were common in many parts. The island, up to 2 m above sea level, was composed of basalt boulders and cobbles built up from core stones derived from basalt hexagon columns of the shore platform. An area of peaty soil in between hummocks had been mined for fertiliser in the 1920s and overlayed silts which were probably old salt marshes formed when the sea level was higher and the island was being built up. The blackwood scrub flowered prolifically but set seed was very rare – due probably to the effects of salt aerosols. Blackwood bushes were severely attacked by wood-boring larvae and regeneration took place entirely by root suckers. Genetic analysis suggested that the population consisted of two groups – probably a founder-effect of chance distribution from the mainland when sea levels fell. After six years of research, this work was published in the *Proceedings of the Royal Society of Victoria*, 1999.

Conclusions

For over 53 years the McCoy Society provided an important venue for the pooling of ideas and cooperative field research between diverse disciplines. The value of such interactions cannot be over-emphasised in the present-day climate of specialisation and economic rationalism where work tends to be done in isolation and with limited budgets. Although the Society has been formally disbanded, the door is still open for its re-emergence should a group of keen people so desire.

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Captions for Colour Plates

Plate 1. *Prodromus of the Zoology of Victoria*, Volume II, Decade XX. Plate 198. Lithograph by A. Bartholomew and Dr J.J. Wild under the direction of Professor McCoy, printed by Government Printing Office. Australian Admiral Butterfly *Pyrameis itea* (figs. 1-4); The Blue-spotted Painted-Lady Butterfly *Pyrameis Kershawi* (McCoy) (figs. 5-8).

Plate 2. *Prodromus of the Zoology of Victoria*, Volume II, Decade XVI. Plate 160. Lithograph by Dr J.J. Wild under the direction of Professor McCoy, printed by Government Printing Office. The Yarra Spiny Cray-fish *Astacopsis serratus* (Shaw sp.), var. *yarraensis* (McCoy).

Plate 3. *Prodromus of the Zoology of Victoria*, Volume I, Decade VI. Plate 53. Lithograph by A. Bartholomew under the direction of Professor McCoy, printed by G. Troedel & Co. The Green and Golden Bell-frog *Ranoidea aurea*.

Plate 4. *Prodromus of the Zoology of Victoria*, Volume I, Decade I. Plate 8. Lithograph by A. Bartholomew under the direction of Professor McCoy, printed by H.G. DeGruchy & Co. Lewin's Day-moth *Agarista Lewini* (figs. 1-4); The Loranthus Day-moth *Agarista casuarinæ* (figs. 5-8); The Vine Day-moth *Agarista glycine* (figs. 9-13).

Plate 5. *Prodromus of the Zoology of Victoria*, Volume I, Decade VIII. Plate 82. Lithograph by Dr J.J. Wild under the direction of Professor McCoy, printed by Government Printing Office. The Murray Tortoise *Chelymys Macquaria* (side view).

Plate 6. (top) *Prodromus of the Zoology of Victoria*, Volume I, Decade VIII. Plate 83. Lithograph by Dr J.J. Wild under the direction of Professor McCoy, printed by Government Printing Office. The Murray Tortoise *Chelymys Macquaria* (ventral and dorsal view).

Plate 6. (bottom) Helmeted Honeyeater. *Ptilotis cassidix* (*Lichenostomus melanops cassidix*). From John *Gould's Birds of Australia* Supplement (1867). Photographed at Museum Victoria by Anne Morton.

Plate 7. *Prodromus of the Zoology of Victoria*, Volume II, Decade XVI. Plate 151. Lithograph by Dr Wild under the direction of Professor McCoy, printed by Government Printing Office. Gould's Monitor Lizard *Monitor Gouldi*.

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Plate 4

Plate 5

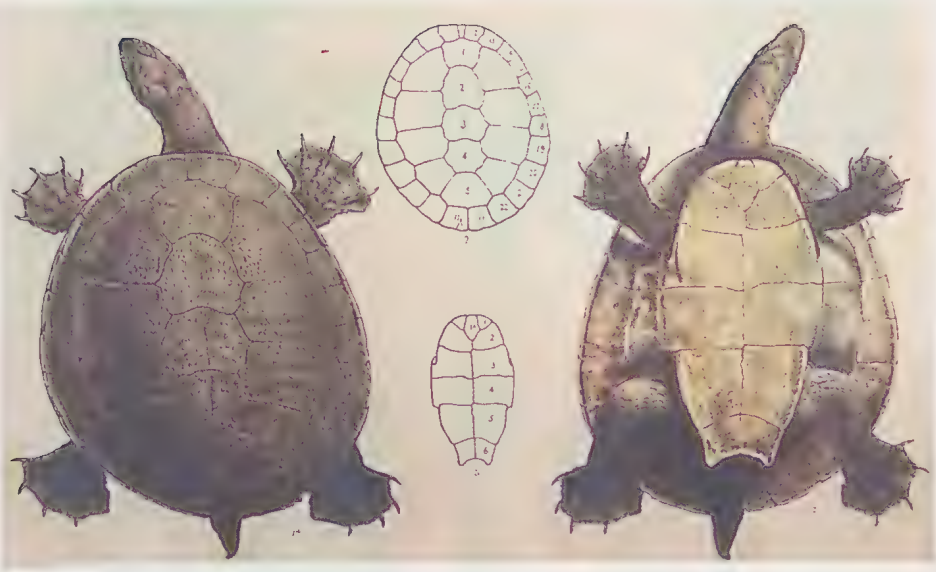

Plate 6

Plate 7

The Victorian Naturalist

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From the Editors

Some changes have been made to the *Guidelines for Authors* that appear at the end of this issue. Authors are asked to carefully read the guidelines and consult the most recent issue of the journal when preparing a manuscript for publication.

The Victorian Naturalist would not be successful without the enormous amount of time and effort given voluntarily by a large number of people who work behind the scenes.

One of the most important editorial tasks is to have papers refereed. The Editors would like to say thank you to those people who refereed manuscripts during 2001:

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The Victorian Naturalist publishes articles for a wide and varied audience. We have a team of dedicated proof-readers who help with the readability and expression of our articles. We would especially like to acknowledge Virgil Hubregtse and Michael McBain who proof read all of the manuscripts for our two McCoy special issues. For proof-reading of the other issues, thanks to:

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Volume 119 (1) 2002 February

Executive Editor: Merilyn Grey
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Research Reports

The Fish of Kororoit Creek – Stressed Relicts and City Slickers, *by Paul G Close* 4

The Mammal Fauna of Remnant Native Grasslands of the Western Basalt Plains and Northern Plains of Victoria, *by Susan A Hadden* 14

How Do Nectar Foraging Butterflies Select Flowers? *by Melissa B Nunn* 21

Contributions

Hooded Plover *Thinornis rubricollis* Chick Attacked by Conspecifics, *by V Teoh and MA Weston* 27

Invertebrates of Mount McKay – a Brief Survey, *by EJ Grey* 29

Naturalist in the Mountains

The Biodiversity Blitz, *by Ken Green* 36

Honours

Australian Natural History Medallion 2001 – Alan Bridson Cribb, *by Ian Endersby* 38

Tributes

Graham Martin Pizzey, *by Sheila Houghton* 39

Book Reviews

Wyperfeld: Australia's First Mallee National Park, *by Geoff Durham, reviewed by Sara Maroske* 40

How to Identify Wildflowers of the Grampians, *by Ken Woodcock, reviewed by Margaret Corrick* 44

New Guidelines for Authors at the end of this issue

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Cover: Dr Alan Cribb, the 2001 Australian Natural History Medallion recipient, with his wife Dr Joan Cribb, (ANH Medallion recipient in 1994). Photo: Wendy Clark. Empathy Photographics.

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The Fish of Kororoit Creek – Stressed Relicts and City Slickers

Paul G Close[1]

Abstract
Kororoit Creek is a metropolitan watershed in which human disturbances may have reduced the health of aquatic fauna populations. Identifying changes in the distribution, diversity and abundance of aquatic fauna is hindered by a paucity of biological information, especially with regard to fish. Intensive surveys conducted during January 2000 quantified the species richness and abundance of fish and decapod crustacea at six sites in Kororoit Creek. A total of nine freshwater and one estuarine fish species was collected, of which five were native species representing approximately 50% of the native taxa expected to occur in the catchment. The relative abundance of exotic species tended to be high in the lower catchment and very low in the mid- to upper catchment. This study identifies a number of anthropogenic factors affecting aquatic fauna populations in Kororoit Creek. (*The Victorian Naturalist* **119** (1), 2002, 4-13)

Introduction

With increasing urbanisation and industrialisation, there is increasing pressure on the ecological integrity or 'health' of aquatic ecosystems (e.g. Klein 1979; Growns *et al.* 1998; Sonneman *et al.* 2001; Walsh *et al.* 2001). Until recently, few investigations into the ecology of urban watersheds and their aquatic fauna have been reported, making assessment of human disturbances on these environments difficult. In particular, there is little information regarding the diversity, abundance and distribution of fish species in urban systems. Furthermore, historical fish data are often compromised by survey methodology and design. For example, whilst the health of Kororoit Creek has been described based on macroinvertebrate populations (Papas *et al.* 2000) and physical and chemical characteristics such as instream and riparian habitat and water quality (Mitchell 1990; Melbourne Water 1997), previous studies of fish in the catchment are limited by age (McKenzie and O'Connor 1989) and geographical extent (McGuckin 1999; DNRE 2000).

Nevertheless, there is increasing recognition of the intrinsic value of urban streams and their associated flora and fauna. Basic biological data, such as species richness, abundance and distribution can provide important information for the conservation of values such as biological diversity, research and education, and aesthetics. In an attempt to determine the health of streams in the Melbourne area and identify priority management areas, Melbourne Water Corporation has established a stream health assessment program including ongoing monitoring programs such as the Melbourne Water Water Quality Monitoring Network, Biological Monitoring Program and the Tributary Investigation Program. These Programs combine a range of stream health indicators (e.g. fish and macroinvertebrate assemblages and water quality) at various temporal and spatial scales. In 1999, Melbourne Water commissioned the Arthur Rylah Institute for Environmental Research to assess the current state of fish assemblages in Kororoit Creek as part of the Tributary Investigation Program.

This paper reports the species richness, abundance and distribution of fish and decapod crustacea in Kororoit Creek and identifies anthropogenic disturbances potentially impacting on the integrity of aquatic fauna populations. This provides valuable base-line information with which future monitoring events may be compared.

Methods

Study area

Kororoit Creek catchment covers an area of approximately 250 km^2 (Fig. 1). Stream flow is intermittent, with zero discharge occasionally recorded at the hydrographic station near Deer Park (station number 5509) (McGuckin 1999). Although stream flow is intermittent and ephemeral in the upper reaches, Kororoit Creek is dominated by long and relatively deep pools, which may provide refugia for aquatic

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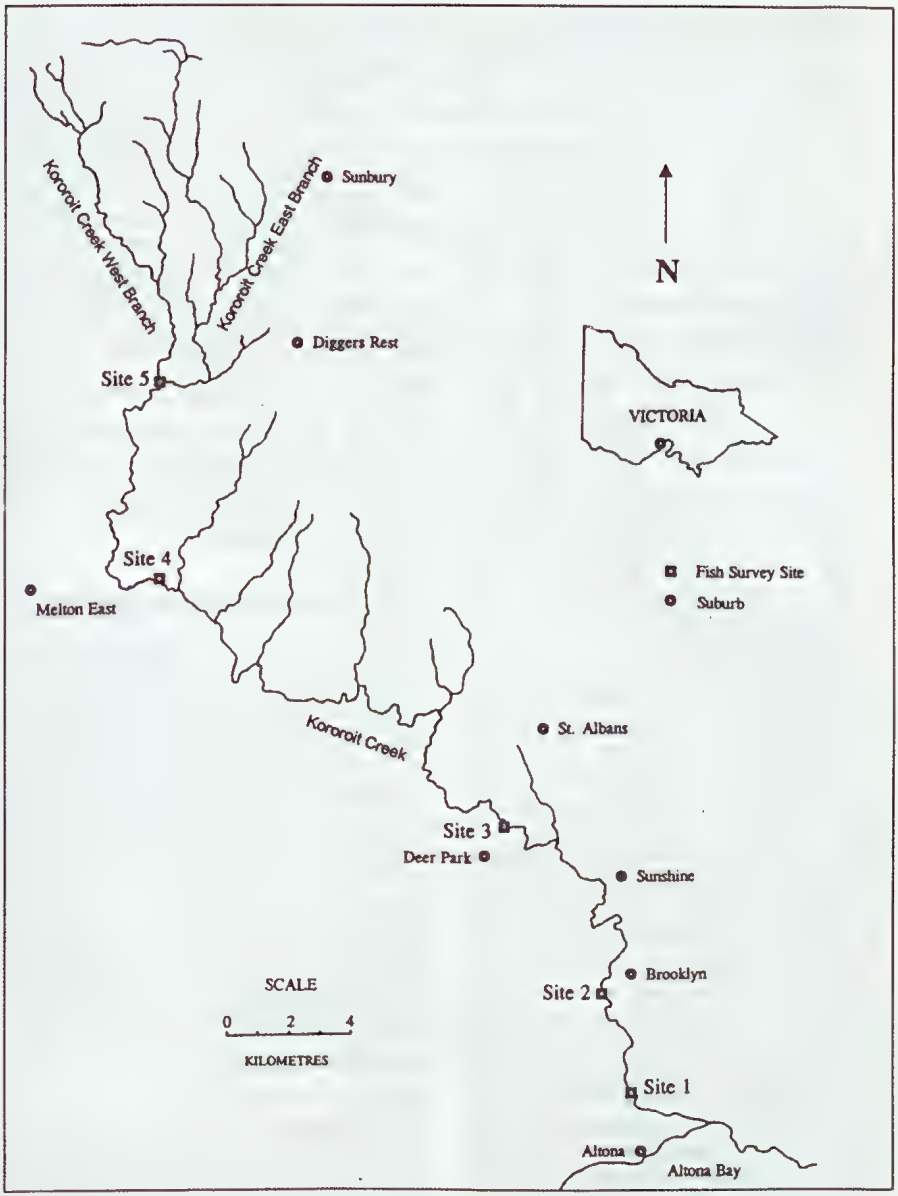

Fig. 1. Location of sites in Kororoit Creek where aquatic fauna surveys were undertaken.

fauna during periods of low flow if instream habitat becomes discontinuous. The catchment relief is relatively low, with the headwaters rising just south of Gisborne at an altitude of approximately 460 m above sea level (m ASL) in basalt country of the Great Dividing Range. Kororoit Creek is approximately 80 km in length and flows in a south-easterly direction through rural farmlands in the headwaters and mid-catchment and urban/industrial areas in the mid-catchment and coastal lowlands. Kororoit Creek flows into Port Phillip Bay near Altona.

Quantification of site attributes

Five study reaches were selected along the length of Kororoit Creek (Fig. 1), based primarily on altitude and distance to river mouth. Within each study reach, a single survey site was established to represent the available aquatic habitat attributes, including flow type and cover elements. At site 3, an additional survey reach was established to include a reach of riffle habitat. Although riffle habitat is scarce in the mid-reaches of Kororoit Creek, riffles often support different assemblages of fish species (see Matthews 1998 for a recent review).

For each survey reach, the mean width and mean maximum depth (m) was calculated from at least five measurements of each dimension. Spot measurements of water quality parameters were recorded within each survey reach. Water temperature (°C) and electrical conductivity (µS/cm at 25°C) were measured with a WTW LF 320 meter, dissolved oxygen (mg/L) with a WTW OXI 320 meter and pH with a WTW pH 320 meter.

The relative abundance (% of wetted area) of hydraulic units, habitat attributes and cover elements was estimated for each survey reach. Hydraulic units at each site were defined using the following categories: cascade, rapid, riffle, glide, run, pool or backwater (after Anderson and Morrison 1989; Anderson *et al.* 1989). Substrata were described in terms of the percentage composition of various particle size groups, namely boulder (particle size >256 mm), cobble (64-255 mm particle size), pebble (16-63 mm particle size), gravel (2-15 mm particle size), sand (0.1-2 mm particle size) and silt/clay (particle size <0.1 mm). The relative abundance of dominant cover elements, including substratum, woody debris (logs, branches), leaf litter (including bark), bank overhang, vegetation overhang and aquatic vegetation, was also estimated and recorded.

Aquatic fauna survey

Surveys were conducted during January 2000. All sites (except site 2) were surveyed using a consistent array of several different net types including single-winged fyke nets, fine mesh larval nets (200 µm mesh), and bait traps. A combination of a single cyalume light stick and a small quantity of cat food was placed in each bait trap to attract fish. The wetted time (fishing time) for each net was recorded. Site 2 and the riffle habitat at site 3 were surveyed using a two-pass bank-mounted (Smith-Root® 7.5GPP electrofishing unit) electrofishing technique with fine mesh nets blocking the downstream and upstream margins of the survey reach. Voltage settings ranged from 170 to 340 V to produce approximately 10 amps. For these sites, the length of the survey reach (m) and the electrofishing time (min; total time during which electrical current is applied to the water) taken to complete each pass were recorded.

All fish and decapod crustacea collected were identified and counted. Nomenclature for fish species follows Allen (1989) and Paxton *et al.* (1989), and Horwitz (1990) for decapod crustacea.

Analyses

Catch per unit effort, fish biomass and density

Estimates of catch per unit effort (CPUE) were calculated for both netting surveys and electrofishing surveys. For netting surveys, CPUE was calculated for each netting technique and expressed in terms of the number of fish collected per hour. The wetted time for individual nets was summed to give a total wetted time and was used in the calculation of total CPUE for each site. CPUE for electrofishing surveys was also expressed in terms of the number of fish collected per hour using the summed time of two electrofishing passes. Estimates of biomass (g/m^2) and density (fish/m^2) were only calculated for electrofishing surveys.

Results

Site descriptions

The five survey sites were distributed evenly throughout the catchment in terms of altitude and distance from river mouth (Fig. 1; Table 1). The uppermost site (site 5) was located near the headwaters of Kororoit Creek at an altitude of 155 m ASL and 40 km from the river mouth. Sites 4 and 3 were located in the mid-catchment at altitudes of 100 and 50 m ASL and 32 and 15 km to river mouth, respectively. Site 2 was located on the

Table 1. Characteristics of the stream, reach and instream habitat for each of the study sites located on Kororoit Creek. Substrata and instream cover are defined in the text.

Habitat Survey Characteristics	Site 5	Site 4	Site 3 *	Site 3	Site 2 *	Site 1
Stream Characteristics						
Elevation (m ASL)	155	100	50	50	15	5
Distance to river mouth (km)	40	32	15	15	6	3
Discharge ML/day	0.0	-	0.9	1.8	3.8	-
Reach Characteristics						
Mean stream width (m)	6.8	11.8	3.6	4.5	5.5	25.8
Mean depth (m)	0.8	2.6	0.3	2.4	0.7	1.8
Water Quality						
Temperature (°C)	24.7	22.1	18.4	21.2	19.5	23.5
Electrical conductivity (µS/cm)	520	1973	2290	1697	2360	2560
Dissolved oxygen (mg/L)	2.2	3.8	3.2	3.8	9.0	7.8
pH	7.1	7.2	7.4	7.4	8.0	7.9
Substratum (Composition %)						
Sheet rock	-	-	-	-	-	-
Boulder	20	20	15	10	30	20
Cobble	-	10	30	-	20	-
Pebble	-	-	5	-	-	-
Gravel	-	-	5	-	5	5
Sand	5	20	-	-	5	5
Silt	75	30	10	90	40	40
Clay	-	20	40	-	-	30
Instream Cover (% of wetted area)						
Substrate (Rock)	3	20	30	-	15	-
Logs/Log jams	5	5	-	-	-	-
Branches/Branch piles	5	10	-	2	-	2
Leaf litter	-	5	5	-	-	5
Bank overhang	10	-	-	10	10	-
Vegetation overhang	5	5	-	10	-	-
Urban rubbish	-	-	10	2	10	5
Aquatic vegetation	5	15	20	20	20	20
Flow Type (%)						
Rapid/cascade	-	-	-	-	-	-
Run	-	-	45	-	-	-
Riffle	-	-	35	-	10	-
Glide	-	-		-		100
Pool	100	100	20	100	90	-
Backwater	-	-	-	-	-	-
Reservoir/lake	-	-	-	-	-	-
Tidal	-	-	-	-	-	-

* denotes sites surveyed using electrofishing techniques.

coastal lowlands 6 km from the river mouth at an altitude of 15 m ASL. Site 1 was located on the coastal margin, 3 km from the river mouth at an altitude of 5 m ASL. This site represented the upper limit of estuarine influence.

Except for site 2, instream substrata were dominated (>50%) by finer particles, namely sand and silt/clay, with the remaining substrata comprised of boulders and/or cobbles (Table 1). The substratum at site 2 comprised approximately equal proportions of silt (40%) and coarser particles of cobbles and boulders (50% combined). Instream habitat that may provide cover for aquatic fauna varied between sites. At the majority of sites, cover was predominantly emergent aquatic vegetation (*Typha* sp. and *Phragmites australis*) and rocky substratum (Table 1). At sites 3, 4 and 5 cover was present in the form of overhanging banks and overhanging terrestrial vegetation. Instream woody debris (logs and branches) only contributed small amounts of cover and was present at all sites except site 2 (Table 1).

Stream discharge was recorded for each survey site on the day of survey except for sites 4 and 1 where a suitable discharge transect could not be established. Discharge estimates varied between sites

Table 2. Freshwater native and exotic fish species previously recorded from Kororoit Creek, and their current conservation status.

Species	Common Name	Conservation Status	Reference
Native			
*Anguilla australis**	Short-finned Eel	CW	McKenzie and O'Connor (1989) McGuckin (1999)
*Galaxias maculatus**	Common Galaxias	CW	McKenzie and O'Connor (1989) McGuckin (1999)
Nannoperca australis	Southern Pygmy Perch	CW	DNRE (2001)[1]
Philypnodon grandiceps	Flat-headed Gudgeon	CW	McKenzie and O'Connor (1989) McGuckin (1999)
*Pseudaphritis urvillii**	Tupong	CW	DNRE (2001)[1] McGuckin (1999)
Retropinna semoni	Australian Smelt	CW	McKenzie and O'Connor (1989)
Macquaria australasica [#]	Macquarie Perch	FFG listed	DNRE (2001)[2]
Exotic			
Carassius auratus	Goldfish	-	
Gambusia holbrooki	Eastern Gambusia	-	
Tinca tinca	Tench	-	

* Freshwater migratory; [#] Translocated population; [1] Recorded by Museum of Victoria; C = Common, W = Widespread [2] Unpublished survey results (Cadwallader 1981); Conservation status follows DNRE (2000).

and ranged from zero near the headwaters (site 5) to 3.8 ML/day at site 2 in the mid-catchment (Table 1). Water quality parameters also varied between sites (Table 1). Dissolved oxygen was generally low, ranging from 2.2 mg/L at the uppermost site (site 5) to 9.0 mg/L at site 2 (Table 1). Electrical conductivity was high at all sites (>1500 µS/cm) except the uppermost site (site 5) (Table 1). At all sites pH was alkaline and tended to increase slightly in alkalinity closer to the river mouth.

Historical data

Few fish surveys have been conducted in Kororoit Creek, with most records of species richness and distribution from McKenzie and O'Connor (1989) and McGuckin (1999). Ten species of fish have previously been recorded in the system (DNRE 2001) (Table 2). Seven species are native, and of these, three are considered diadromous (i.e. migrate between freshwater and estuarine marine habitats at particular stages of their life; Table 2). The Macquarie Perch *Macquaria australasica* is native to Australia but is not endemic to Kororoit Creek. While 50 Macquarie Perch were stocked in 1912 at Sunshine, this species has not subsequently been recorded (DNRE 2001). A recent collection of Tupong *Pseudaphritis urvillii* in Kororoit Creek (McGuckin 1999) is the first record of this species since 1894 by the Museum of Victoria (DNRE 2001). The only record of Southern Pygmy Perch *Nannoperca australis* is from 1934 and the specimen is held at the Museum of Victoria.

Three exotic fish species have previously been recorded from Kororoit Creek (Table 2). Tench *Tinca tinca* were recently collected in Kororoit Creek for the first time since they were stocked in 1914 (McGuckin 1999; DNRE 2001).

Survey results

Species distribution

Aquatic fauna surveys were conducted over a period of 8 days between 17 and 25 January 2000. A total of nine species of freshwater fish was recorded, of which five (55%) were native (Table 3). Three of these native species are diadromous. One estuarine species, Tamar River Goby *Afurcagobius tamarensis*, was collected at the most downstream site (site 1). Two genera of decapod crustacea were collected in Kororoit Creek. Although no specimens were collected, an additional genus of decapod crustacean, *Engaeus*, was also recorded by the presence of their characteristic burrows.

Four exotic fish species were collected in Kororoit Creek (Table 3) including Carp *Cyprinus carpio*, another new species record for Kororoit Creek.

Table 3. Relative abundance (%) of fish species and total number of decapod crustacea collected at each study site.

Species	Site 5 N	Site 4 N	Site 3 N	Site 3 EF	Site 3 EF+N	Site 2 EF	Site 1 N
Teleosts							
Anguillidae							
Anguilla australis (Richardson)	-	10.2	3.7	5.9	4.2	10.0	40.9
Galaxiidae							
Galaxias truttaceus (Valenciennes)	--	--	-	2.8	✓	-	-
Galaxias maculatus (McDowall)	-	-	✓	78.8	23.5	47.5	10.6
Retropinnidae							
Retropinna semoni (McDowall)	-	1.4	1.4	3.1	1.9	3.2	7.0
Cyprinidae							
Carassius auratus (Linnaeus) *	-	-	✓	4.9	1.5	12.3	✓
Cyprinus carpio (Linnaeus) *	-	-	-	-	-	13.7	14.8
Tinca tinca (McDowell) *	-	-	✓	-	✓	-	✓
Poeciliidae							
Gambusia holbrooki (Girard) *	-	✓	✓	2.1	✓	12.8	4.2
Gobiidae							
Philypnodon grandiceps (McCulloch)	-	87.8	93.2	2.4	66.8	✓	17.6
Afurcagobius tamarensis (Johnston)	-	-	-	-	-	-	3.5
Total Number of Fish	**0**	**147**	**1036**	**425**	**1461**	**219**	**142**
Decapod Crustacea							
Parastacidae							
Cherax destructor	149	1	-	1	1	-	-
Atyidae							
Paratya australiensis	-	Present	Present	Present	Present	Present	Present
Number of Species	**1**	**6**	**8**	**9**	**10**	**8**	**10**

Habitat survey characteristics are defined in Table 1. ✓ indicate the presence of the species at low abundances (<1%). * denotes exotic species. N, netting survey. EF, electrofishing survey.

Species composition and richness varied throughout the system. At most sites a range of aquatic fauna species was recorded, except at site 5 in the upper reaches of the system where only one species, Common Yabby *Cherax destructor*, was collected. At the site immediately downstream (site 4), a total of six species was recorded. Aquatic fauna assemblages were most diverse throughout the middle and lower reaches of the system (sites 1, 2 and 3). Species richness ranged from eight to ten species at each of these sites.

Short-finned Eel *Anguilla australis* were collected at all sites except the uppermost site (site 5). The relative abundance of Short-finned Eel was greatest (approximately 40%) at the most downstream site (site 1). At all other sites, the relative abundance ranged from 3.7% at site 3 to 10.2% at site 4.

Spotted Galaxias *Galaxias truttaceas* were collected only at site 3 (12 individuals) using bank-mounted electrofishing techniques. This is the first documented record of this species in Kororoit Creek.

Common Galaxias *Galaxias maculatus* were collected at three sites located in the mid to lower catchment (sites 1, 2 and 3) with relative abundance estimates ranging from <1 to 78.8%. The highest relative abundance was recorded at sites surveyed using electrofishing techniques (sites 2 and 3). Estimates of relative abundance from netting surveys were relatively low (<11%).

Australian Smelt *Retropinna semoni* were collected at all sites except the uppermost site (site 5). The greatest relative abundance (7%) was recorded at the most downstream site (site 1). Relative abundance estimates were similar (approximately 3%) in the two reaches (sites 2 and 3) surveyed using bank-mounted electrofishing techniques.

Flat-headed Gudgeon *Philypnodon grandiceps* were recorded at all sites except the uppermost site (site 5). Relative abundance was high (>80%) at sites sur-

veyed with netting equipment (sites 4 and 3) and lowest at the electrofishing survey sites 2 and 3. Young-of-the-year fish were numerically dominant in samples from sites 3 and 4 (Close 2000).

Tamar River Goby were restricted to estuarine habitats and only three individuals were collected from the most downstream site (site 1). Tamar River Goby comprised 3.5% of the total number of fish collected at this site.

Of the exotic fish species collected, Eastern Gambusia *Gambusia holbrooki* was the most widespread, occurring at all sites where fish were caught. Estimates of relative abundance were generally low (<5%), except at site 2 where they contributed 12.8% of the total catch. Goldfish *Carassius auratus* exhibited a similar distribution and relative abundance, being collected at three sites (sites 1, 2 and 3) with the highest relative abundance (12.3%) recorded at site 2. Tench were only collected at two sites (sites 3 and 1) and were present in low abundance. Similarly, Carp were only collected from the two most downstream sites (sites 1 and 2).

Catch per unit effort, fish biomass and density

The results of netting and electrofishing surveys were different in terms of both species richness and species abundance, and catch per unit effort (CPUE) (c.f. Tables 4 and 5). CPUE for netting surveys at four sites ranged from 0.34 to 2.66 fish/hr (Table 4). In comparison, CPUE for electrofishing surveys conducted at sites 2 and 3 was 114.3 and 269.1 fish/hr respectively (Table 5). At site 3, where both netting and electrofishing survey techniques were employed, both these techniques recorded similar species except for Spotted Galaxias and the Common Yabby that were only collected by electrofishing (Table 5).

The efficiency of the different netting techniques used in this survey varied between sites, although larval nets proved to be the most efficient netting technique at all sites (Table 4). Flat-headed Gudgeon dominated species abundance and CPUE for larval nets. At site 5, only one species, the Common Yabby, was recorded in larval nets. The only large-bodied native fish recorded in Kororoit Creek was the Short-finned Eel. Other large-bodied fish present in the catchment were exotic species, namely Carp, Tench and Goldfish. Fyke nets represented the only efficient technique to capture these larger-bodied species.

Discussion

Species distribution and abundance

The composition and species richness of aquatic fauna assemblages varied between survey sites within Kororoit Creek. In general, species richness was greatest in the mid- to lower catchment (sites 3, 2 and 1). Species richness decreased with increasing distance from the creek mouth to a minimum at the uppermost site (site 5) where only one species, Common Yabby, was collected. The relative abundance of exotic species in aquatic fauna populations ranged from zero to 38.8% and generally increased with increasing distance from source.

The collection of Spotted Galaxias and Carp represent the first documented records of these two species in Kororoit Creek. In a recent survey of the system by McGuckin (1999), Tupong was collected in a fyke net survey near Clarkes Road, Rockbank. Tupong was the only species recently recorded in the catchment that was not collected in this study. While there are historical records of Southern Pygmy Perch and Macquarie Perch, both from the early 1900s, neither species was collected in the present study.

The low abundance of the migratory Tupong recorded by McGuckin (1999) and the absence of Tupong and Southern Pygmy Perch in the present survey is of conservation concern, as the reasons for their poor representation in fish assemblages is unknown. In Victoria, Tupong are considered diadromous, with adult fish migrating downstream to estuaries to spawn during autumn and winter (Andrews 1996). Upstream migration of juvenile Tupong from estuaries into riverine reaches has also been described during spring and summer. Only one instream barrier to fish movement is documented on Kororoit Creek (McGuckin 1999). Although this barrier may allow fish passage at some high flows (McGuckin 1999), its presence, along with other possible barriers, may contribute to the low abundance of Tupong

Table 4. Results of netting surveys including the number and type of netting equipment used at each site, pooled wetted time, and abundance (in parentheses) of each species collected. Catch per unit effort (CPUE) for each net type is expressed in terms of number of fish caught per hour of wetted net time.

Type and Number of Nets	Pooled Wetted Time (hrs)	Species	Total Number of Fish/Decapod Crustacea	CPUE fish/hr	Total CPUE fish/hr
Site 1					
Fyke - 5	96.7	Aa (58), Cc (7), Tt (1)	66	0.7	
Mesh 3" - 1	19.3	Ca (1), Cc (4)	5	0.3	
Mesh 4" - 1	19.3	Cc (2)	2	0.1	0.82
Larval - 2	38.7	At (2), Cc (4), Gm (15), Gh (6), Pg (26), Rs (10)	62	1.6	
Bait Trap - 10	193	At (3), Pg (4)	7	0.05	
Site 3					
Fyke - 8	156	Aa (37), Gm (1), Pg (1), Tt (4)	43	0.3	
Larval - 2	39	Aa (1), Pg (961), Gm (5), Gh (3), Rs (14), Tt (3)	987	25.3	2.66
Bait Trap - 10	195	Ca (1), Gm (2), Pg (4)	7	0.05	
Site 4					
Fyke - 9	184.5	Aa (13), Pg (4)	17	0.1	
Larval - 2	41.0	Aa (2), Cd (1), Gh (1), Pg (110), Rs (2)	116	2.8	0.34
Bait Trap - 10	205	Pg (15)	15	0.1	
Site 5					
Fyke - 4	69	Cd (24)	24	0.3	
Larval - 2	34.5	Cd (71)	71	2.1	0.54
Bait Trap - 10	172.5	Cd (54)	54	0.3	

Abbreviations denote species: Aa, Short-finned Eel *Anguilla australis*; At, Tamar River Goby *Afurcagobius tamarensis*; Ca, Goldfish *Carassius auratus*; Cc, Carp *Cyprinus carpio*; Gh, Eastern Gambusia *Gambusia holbrooki*; Cd, Common Yabby *Cherax destructor*; Gm, Common Galaxias *Galaxias maculatus*; Gt, Spotted Galaxias *Galaxias truttaceus*; Pg, Flat-headed Gudgeon *Philypnodon grandiceps*; Rs, Australian Smelt *Retropinna semoni*; Tt, Tench *Tinca tinca*.

Table 5. Results of electrofishing surveys at sites 2 and 3, including electrofishing time, area sampled, species diversity, abundance and biomass. Estimates of fish biomass, density and catch per unit effort (CPUE) are also provided.

Sample time (hrs)	Area Sampled (m^2)	Species Biomass (g)	Biomass g/m^2	Total Number of Fish	Density $fish/m^2$	CPUE fish/hour
Site 2						
1.92	546	Aa (2774)	7.68	Aa (22)	0.40	114.3
		Ca (406.2)		Ca (27)		
		Cc(323.7)		Cc (30)		
		Gh (15.5)		Gh (28)		
		Gm (661.7)		Gm (104)		
		Pg (4.6)		Pg (1)		
		Rs (8.1)		Rs (7)		
Site 3						
1.58	362	Aa (1773)	9.0	Aa (25)	1.2	269.1
		Ca (470.3)		Ca (21)		
		Cd (7.7)		Cd (1)		
		Gh (5.3)		Gh (9)		
		Gm (960.8)		Gm (335)		
		Gt (50.7)		Gt (12)		
		Pg (2.9)		Pg (10)		
		Rs (1.3)		Rs (13)		

Abbreviations denote species: Aa, Short-finned Eel *Anguilla australis*; Ca, Goldfish *Carassius auratus*; Cc, Carp *Cyprinus carpio*; Gh, Eastern Gambusia *Gambusia holbrooki*; Cd, Common Yabby *Cherax destructor*; Gm, Common Galaxias *Galaxias maculatus*; Gt, Spotted Galaxias *Galaxias truttaceus*; Pg, Flat-headed Gudgeon *Philypnodon grandiceps*; Rs, Australian Smelt *Retropinna semoni*.

Table 6. The proportion of species recorded (bold) at each site expressed as a percentage of the total number of expected species (non-bold) and the relative abundance (%) of exotic fish at each site.

Site	Expected native species	% of expected	% exotic abundance
1	**Aa**, Gau, **Gm**, Gt, Mm, **Pa**, **Pg**, Pm, Pu, **Rs**	50	20.4
2	**Aa**, Gau, **Gm**, Gt, Mm, Na, **Pa**, **Pg**, Pm, Pu, **Rs**	45.5	38.8
3	**Aa**, **Cd**, Gau, **Gm**, **Gt**, Mm, Na, **Pa**, **Pg**, Pu, **Rs**	54.5	2.7
4	**Aa**, **Cd**, Gau, Gm, Gt, Mm, Na, **Pa**, **Pg**, Pu, **Rs**	45. 5	0.6
5	Aa, **Cd**, Gm, Na, Pa, Pg, Rs	14.3	0

* denotes migratory species. Abbreviations denote species: *Aa, Short-finned Eel *Anguilla australis*; Cd, Common Yabby *Cherax destructor*; *Gau, Pouched Lamprey *Geotria australis*; *Gm, Common Galaxias *Galaxias maculatus*; Gt, Spotted Galaxias *Galaxias truttaceus*; *Mm, Short-headed Lamprey *Mordacia mordax*; Na, Southern Pygmy Perch *Nannoperca australis*; Pa, Freshwater Shrimp *Paratya australiensis*; Pg, Flat-headed Gudgeon *Philypnodon grandiceps*; *Pm, Australian Grayling *Prototroctes maraena*; Rs, Australian Smelt *Retropinna semoni*; *Pu, Tupong *Pseudaphritis urvillii*.

by inhibiting recruitment of young fish migrating upstream from estuarine areas.

Southern Pygmy Perch has not been recorded in Kororoit Creek since 1934, although it has been collected in nearby tributaries of the Werribee River (DNRE 2001). Kororoit Creek is considered to have a significant amount of potentially suitable habitat (abundant submerged/aquatic vegetation) for Southern Pygmy Perch (pers. obs.) and its absence in samples from recent surveys is currently unexplained.

Impacts on the Kororoit Creek System

Numerous factors potentially affect the environmental condition of Kororoit Creek, and more specifically, populations of aquatic fauna. In general, these impacts relate to the whole catchment, although there are additional disturbances that are site specific. Impacts on aquatic fauna populations in Kororoit Creek include urbanisation and industrialisation, mainly in the mid- to lower reaches of the catchment; clearing of native riparian vegetation and the introduction of exotic plant species; bed and bank instability, mainly in agricultural areas in the upper catchment; barriers to fish migration; introduction of exotic species; and alteration of the natural flow regime.

As with many other aquatic ecosystems in Victoria (Koehn and O'Connor 1990), habitat loss or alteration is considered a primary factor that has an impact on the health of aquatic fauna populations in Kororoit Creek (Close 2000). To assess the condition of fish populations, a list of taxa expected to occur at each site on Kororoit Creek was compiled using available historical survey data (DNRE 2001) and refined using knowledge of distribution and habitat requirements of Victorian fish species. The richness of freshwater fish species at sites located on the coastal margin (site 1) and coastal lowlands (site 2) was approximately 50% of the total expected species richness, and the relative abundance of exotic species ranged from 20.4 to 38.8% (Table 6). Similarly, approximately 50% of the species expected to occur at sites in the mid- to upper catchment (sites 3 and 4) were recorded in this study, although the relative abundance of exotic species was very low (2.7 and 0.6%, respectively). The species richness recorded from the upper catchment (site 5) in this study represented only 14.3% of what was expected to occur. No exotic species were recorded at this site.

The composition of fish assemblages may vary temporally and respond to variations (natural or anthropogenic) in stream discharge, water quality, habitat structure and the abundance of food as a result of variations in spawning, recruitment and recolonisation success (see Matthews 1998 for a recent review). Nevertheless, the species composition of fish assemblages recorded in this survey appears altered from that which would be expected to occur naturally in Kororoit Creek: native species richness appears reduced and exotic species have been introduced. Those species not recorded in the current survey which are expected to occur in the catch-

ment are Pouched Lamprey *Geotria australis*, Short-headed Lamprey *Mordacia mordax*, Southern Pygmy Perch *Nannoperca australis*, Tupong *Pseudaphritis urvillii* and Australian Grayling *Prototroctes maraena*. Whilst ongoing monitoring will provide a better understanding of the dynamics of the Kororoit Creek fish assemblage, the data discussed here, coupled with the identification of potentially numerous anthropogenic impacts on the health of Kororoit Creek, suggest that the current fish assemblage may represent stressed and relict native species as well as exotic species or 'city slickers' which may be more resilient and resistant to disturbed environments.

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Vale Jack Hyett

Members of The Field Naturalists Club of Victoria will be saddened to learn of the death of Jack Hyett in July 2001. Jack was an honorary life member of the Club and an Australian Natural History Medallionist. A tribute to Jack will appear in a later issue.

The Mammal Fauna of Remnant Native Grasslands of the Western Basalt Plains and Northern Plains of Victoria

Susan A Hadden[1]

Abstract
Twenty-four native grassland remnants in the Western Basalt and Northern Plains of Victoria, Australia, were investigated to determine the composition of the mammal fauna and evaluate their habitat use. These sites included remnants that had differing levels of grazing pressure, structural attributes and floristic diversity. Mammals were assessed by pitfall trapping and systematic searching. Grassland characteristics, representing structure and diversity, that might affect the mammal species richness of the grassland were recorded. Five mammal species were recorded in the Western Basalt Plains and four in the Northern Plains. Sites with light grazing, open ground cover and high native plant richness favoured native mammal species. (*The Victorian Naturalist* **119** (1), 2002, 14-20)

Introduction

In many regions of Australia, only disjunct remnants of the original forest, woodland and grassland vegetation remain within an expanse of cleared agricultural land (Kitchener *et al.* 1980; Bennett 1990). Remnants are under continuing pressures from a variety of pastoral activities, including grazing, fire and pasture 'improvement'. Their ability to cope with changes in management is of great interest. Because most vertebrate fauna have not successfully adapted to modified environments, remaining patches of natural vegetation are of importance to the regional conservation of the indigenous fauna (Bennett 1987a; Hadden and Westbrooke 1996). With increasing loss and fragmentation of the natural habitat, determining both the consequences of habitat fragmentation for faunal communities and the characteristics of remnants that favour fauna conservation – in particular, the role of disturbance – is essential.

Native grasslands have been identified as one of the most threatened ecosystems in Victoria (Groves 1979; DCE 1990, 1992; Lunt 1991; McDougall and Kirkpatrick 1994; Foreman 1996). Prior to European settlement they covered approximately 30% of Victoria, occurring across the western and northern plains, generally confined to the lowlands, below 500 m altitude. The western and northern plains lie within the two natural regions of the Volcanic Plains and Riverina of Victoria (Conn 1993). Grasslands may appear to be simple-structured communities (Lunt 1991); however, they are complex at the small scale (Patton 1935). Their complexity arises from their diverse floristic and faunal composition and the interaction between these elements (Lunt 1991; Morgan 1994). They have been largely cleared for agriculture because the fertile soils were suited to pasture improvement and cropping, with the structure of remaining grassland remnants being severely reduced by cultivation.

The aim of this research was to document the occurrence and abundance of ground-dwelling mammal species in native grasslands and relate these to the importance of vegetation structure.

Methods

Study sites

Twenty-four grassland remnants were surveyed for ground-dwelling mammals. These sites included remnants that had different levels of grazing pressure, structural attributes and floristic diversity.

The Western Basalt Plains comprise a series of lava flows, which are interrupted in places by outcropping of other rock types. The flat to undulating basalt plains on which the community occurs cover approximately 21,000 km^2 of Victoria. The area is bounded by Melbourne in the east, Hamilton in the west, Beaufort to the north and Colac to the south. The average annual rainfall ranges between 500 and 800 mm, most falling between April and November. The soils of the Western Basalt Plains are described as duplex clays, with a shallow clay and humus profile overlying another

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less permeable clay layer, restricting root development and drainage (Conn 1993).

The Riverine Plain of south-eastern Australia is the eastern portion of the Cainozoic sedimentary Murray River Basin dominated by Quaternary alluvial sediments, and occupies a large part of both Victoria and New South Wales (Butler *et al.* 1973). The Victorian portion is typically referred to as the Northern Plain, occupying approximately 25,000 km^2 extending from Wangaratta and Wodonga in the east to Charlton in the west (Conn 1993). It consists of a relatively homogeneous flat to undulating quaternary alluvium land-form, generally receiving less than 400 mm of rainfall per annum. The grasslands and grassy woodlands occur on relatively dry and high ground, away from zones of seasonal inundation. The soils are typically poorly drained with a firm clay surface texture (McDougall *et al.* 1994; Foreman 1996).

Survey methods

Pitfall drift-fence system

The traps consisted of thirteen 20 litre plastic buckets buried in the ground so that the lip was flush with the ground level to form a pit. The traps were arranged in a grid system of 3 × 2 (repeated 2.5 times), 20 m apart. A drift-fence extended through the centre of each trap and extended for 2 m either side. The lower 2 cm of the fence was buried in the ground to prevent animals from crossing under the fence. Holes were drilled in the bottom of each pit to prevent them from filling with water when it rained. Traps were opened for four nights during each survey period and were checked every morning and afternoon, resulting in 52 trap-nights for each site per survey period. All vertebrates trapped were identified and released at the point of capture, with care being taken to minimise any distress to the animals. Mark-recapture (ear-tagging) methods were employed to obtain estimates of abundance.

Systematic and opportunistic searching

Systematic searching involved searching for mammals under logs, behind bark, through ground cover and in water. Any fauna seen or hand-caught were identified and released. Twelve hours of searching were undertaken at each site.

Assessment was undertaken from January 1995 to February 1996. Six surveys, approximately 8 weeks apart, were conducted at each site for each grassland region, involving 7488 trap nights and 288 hours of systematic searching.

Habitat analysis

The habitat variables considered as potentially being important in affecting the richness and abundance of mammal species in remnant native grassland were:

- cover of cool season perennial grass;
- cover of warm season perennial grass;
- cover of native herbs;
- cover of exotic grasses;
- cover of exotic herbs;
- cover of bare ground;
- cover of dry litter material;
- floristic composition (total, natives only and exotics only);
- grazing pressure (sheep per ha and months grazed); and
- invertebrate richness.

The percentage cover of the seven functional groups described above was recorded using the point quadrat method (Goldsmith *et al.* 1986). A 10 m tape measure was laid out through the trapping grid and at every 10 cm point, a steel pin was lowered into the vegetation, and the functional group contacted by this pin recorded. Only one functional group was recorded per point, giving 100 point touches per grassland site. This can be interpreted as the percentage of cover for each functional group. Measurements of cover were recorded seasonally, in conjunction with the trapping session. The botanical composition of the grassland site was determined from the number of vascular plants recorded from a 5 × 5 m quadrat within the trapping grid, during spring. All vascular plants were identified and recorded.

The number of sheep per hectare and the number of months the paddocks are grazed per year defined the grazing pressure. Information about these variables was obtained directly from the relevant landowners.

Invertebrate richness was estimated based on the number of invertebrate orders

at each site. Invertebrates were sampled using small plastic cups filled with alcohol/glycerol solution. Ten cups were placed randomly in the ground throughout the trapping site and sampled during each trapping session.

Species were categorised as common or uncommon, based on records held in the Atlas of Victorian Wildlife (NRE). Faunal species were then given a classification as being rare and/or endangered based on the Atlas of Victorian Wildlife records. Species known from less than 50, 5° latitute/longitude grids, were categorised as uncommon.

Some variables were combined to compare particular trends in the data. The habitat variables of grazing, cover and native plant richness were classified into groups for an initial review of the data. The variable of grazing was split into lightly and heavily grazed sites and was based on the DSE levels and number of months grazed - those which were grazed all year round with a DSE rating of 3/ha and over were classed as heavily grazed. Those sites that were rested for at least three months of the year and with a DSE of less than 3/ha were lightly grazed sites. The variable of cover was split into open ground cover sites and dense ground cover sites. This was based on the percentage cover of tussocks, with sites having greater than 50% tussock cover classed as dense ground cover sites and those sites with less than 50% tussock cover as open ground cover sites. The variable of native plant richness was split into floristically rich sites and floristically poor sites and was based on the number of native plant species. Those sites which had more than 30 native plant species were classed as floristically rich and those with fewer than 30 native plants were classed as floristically poor.

Statistical analysis

Descriptive statistics were used to list and describe the mammal composition of the native grassland sites. They were used to outline the characteristics of the fauna and to investigate general similarities and differences between the grassland sites.

Results

Two native mammal species were identified within the 24 remnants of native grassland, with both represented in the Western Basalt Plains and one in the Northern Plains. The Fat-tailed Dunnart *Sminthopsis crassicaudata* was found in both grassland regions, whilst the Common Dunnart *S. murina* was only encountered on the Western Basalt Plains with just a single capture at one site. Three exotic species, the Brown Hare *Lepus capensis*, House Mouse *Mus musculus* and European Rabbit *Oryctolagus cuniculus*, were recorded in both regions. Tables 1 and 2 record the abundance of faunal species recorded within each remnant, for each region. Because the European Rabbit and Brown Hare were sighted only and not trapped, accurate abundance levels could not be determined; their presence at a site is indicated by +. All further results and discussion are based on the native species.

Site occurrence of native mammals

Fat-tailed Dunnarts were recorded at every site in the Northern Plains (100%) and seven of the 12 sites in the Western Basalt Plains (58%) (Tables 1 and 2). The single record of the Common Dunnart was at a site in the Western Basalt Plains where Fat-tailed Dunnarts were also recorded. Five of the 12 sites in the Western Basalt Plains revealed no native mammals.

Site occurrence of the House Mouse

The introduced House Mouse occurred at five sites on the Western Basalt Plains (42%) and eight sites on the Northern Plains (67%).

Native mammals in relation to site characteristics and previous information

The most common marsupial, Fat-tailed Dunnart, was abundant at a number of floristically rich sites, but was also found in high numbers on degraded grassland remnants and in exotic pastures. This species has adapted to altered grassland conditions. Found living under stone walls and rock piles, the species was observed to use wolf spider holes on the Northern Plains. It is considered to be a common and widespread species with few concerns about its conservation status. However, at a number of grassland sites around Melbourne, the species has disappeared from areas where it was once in high abundance (Colin Hocking pers. comm.). Very few recaptures were made in this study, and the species may warrant careful survey

Table 1. Mammal species recorded from grassland remnants of the Western Basalt Plains, with numbers of captures during 7488 trap nights. + present but abundance levels not determined; * introduced species.

Species	Site 1	2	3	4	5	6	7	8	9	10	11	12
Family Dasyuridae												
Sminthopsis crassicaudata	14	8	9	3	-	-	6	-	4	7	-	-
Sminthopsis murina	-	-	-	-	-	-	1	-	-	-	-	-
Family Muridae												
*Mus musculus**	-	-	-	2	3	1	-	-	-	-	4	2
Family Leporidae												
*Lepus capensis**	-	+	+	+	+	+	+	+	+	+	+	+
*Oryctolagus cuniculus**	-	+	+	+	+	+	+	+	+	+	+	+

Table 2. Mammal species recorded from grassland remnants of the Northern Plains, with numbers of captures during 7488 trap nights. + present but abundance levels not determined; * introduced species.

Species	Site 1	2	3	4	5	6	7	8	9	10	11	12
Family Dasyuridae												
Sminthopsis crassicaudata	11	7	5	7	6	3	5	6	7	4	10	8
Family Muridae												
*Mus musculus**	-	-	-	-	3	2	4	3	2	3	2	1
Family Leporidae												
*Lepus capensis**	-	-	-	-	+	+	+	+	+	+	+	+
*Oryctolagus cuniculus**	-	-	+	-	+	+	-	+	-	+	-	-

over the coming years to assess fluctuations in population numbers and status.

The second species, Common Dunnart, is considered uncommon throughout Victoria despite its name (Morton 1995). All other records for this species are in woodlands (Menkhorst 1995; Morton 1995) so this record from grassland suggests that the species may occupy habitats outside its previously known range.

Mammal abundance and grazing pressure

The relative abundance of the Fat-tailed Dunnart was higher on lightly grazed sites than on heavily grazed sites. The difference was more pronounced on the Western Basalt Plains ($p = 0.002$) and not significant on the Northern Plains ($p = 0.241$). The opposite was observed for the House Mouse which was more abundant on heavily grazed sites. There were no records of the species on the lightly grazed sites of the Western Basalt Plains. This difference was significant for the Western Basalt Plains ($p = 0.001$) but not for the Northern Plains ($p = 0.156$).

Mammal abundance and ground cover

The Fat-tailed Dunnart was more abundant in the open vegetation cover sites than in the dense vegetation cover sites. The difference was more pronounced in the Western Basalt Plains, but not significant in either region ($p = 0.196$ and 0.278 respectively). The House Mouse showed a different response to ground cover in the two regions. On the Western Basalt Plains, sites with a dense ground cover supported significantly higher numbers of House Mouse ($p = 0.003$), whereas on the Northern Plains, sites with open ground cover supported higher numbers of House Mouse ($p = 0.141$).

Mammal abundance and plant species richness

The Fat-tailed Dunnart was more common at the richer native plant sites than at sites which were floristically poor. The dif-

ferences observed on the Western Basalt Plains were significant ($p = 0.002$), but not on the Northern Plains. There were higher numbers of House Mouse on floristically poor sites than on those which were floristically rich. The differences observed on the Western Basalt Plains were significant ($p = 0.003$), but not on the Northern Plains.

Discussion

The mammal fauna

Few mammal species were recorded on native grassland sites on either the Western Basalt Plains or the Northern Plains, with just one native mammal species, Fat-tailed Dunnart, occurring widely in both regions. Fat-tailed Dunnarts were found to be widespread and common in both native grasslands and exotic pastures. Other mammal species, including introduced Brown Rat *Rattus norvegicus* and native Swamp Rat *R. lutreolus* (J Seebeck pers. comm.), have been recorded in grasslands, particularly on the Western Basalt Plains, but were not encountered during this survey. The Fat-tailed Dunnart has a broad geographical distribution, occurring across southern Australia in a variety of vegetation habitats, including open woodland, low shrublands of saltbush and bluebush, tussock grasslands and gibber plains (Morton 1995). It inhabits only lowland areas in the western half of Victoria (Menkhorst 1995). Morton (1995) and Menkhorst (1995) state that unlike most native mammals in Victoria, the Fat-tailed Dunnart appears not to have been greatly disadvantaged by early agricultural developments, and populations survive on improved pasture throughout the Volcanic Plains, Otway Plains, Wimmera and Riverina. Morton (1978a) states that the species is predominately an animal of sparse grassland and open shrubland where there is a significant component of bare ground. From this information on the species, it was expected that captures of Fat-tailed Dunnart would be mainly confined to grassland sites with bare ground a significant component.

The Common Dunnart was found at one site from the Western Basalt Plains and despite its vernacular name, is not common in Victoria. It is most commonly found in woodland, open forest and heathland but has also been recorded near rainforest vegetation (Fox 1995). Sites of Common Dunnart are characterised by sparse shrub and ground cover (<50%), but often with dense leaf and bark litter (Menkhorst 1995). This species has not previously been recorded from grassland vegetation and this record provides a major range extension for the species. The site near Colac is close to woodland vegetation, which may provide an explanation for this record.

Factors influencing abundance of the Fat-tailed Dunnart

The abundance of the Fat-tailed Dunnart appeared to be influenced by a number of habitat characteristics and it was more common on sites that were lightly grazed. This suggests that high levels of grazing may affect the species' abundance, by reducing the availability and quality of ground cover. Sites which had an open ground vegetation cover tended to support greater numbers of Fat-tailed Dunnarts than those which were structurally dense. Because the species is an active forager of insects and other invertebrates, open spaces for hunting prey may be extremely important. Dense vegetation cover at ground level would severely limit the ability of the species to move. However, the need for cover is also important for protection from raptors, foxes and cats and for shelter from adverse weather conditions (Birney *et al.* 1976; Abramsky *et al.* 1979; Grant *et al.* 1982; Alder 1985; Clark *et al.* 1989; Bowles and Copsey 1992). Although burrows in the soil (Northern Plains) and under rock (Western Basalt Plains) are vital for Fat-tailed Dunnarts, some form of tussock cover is required. Selection of sites with open ground cover but with tussock cover minimises the detection by aerial predators.

Potential predators of Fat-tailed Dunnarts, and other native mammals, include introduced Dog *Canis familiaris*; Fox *Vulpes vulpes*; Cat *Felis catus*; native Brown Goshawk *Accipiter fasciatus*; Grey Goshawk *A. novaehollandiae*; Wedge-tailed Eagle *Aquila audax* and Whistling Kite *Haliastur sphenurus* (Bennett 1987b). On grasslands, tussock cover is most effectively provided by scattered tussock grasses *Poa* spp. on the Western Basalt Plains and wallaby grasses *Austrodanthonia* spp. on the Northern Plains.

Cover is also important to the Fat-tailed Dunnart for diurnal shelter, and may ameliorate local weather conditions. The Fat-tailed Dunnart constructs nests within tussocks or other dried plant material beneath rocks and within cracks in the soil. Sites with a greater richness of native plants supported more Fat-tailed Dunnarts. Although the species was found at every site on the Northern Plains and over half of the Western Basalt Plains sites, as well as on all exotic pasture sites, relative abundance did have a slight correlation with native species richness. The more floristically rich sites, which are most likely to be more intact, will presumably support greater numbers of animals. As invertebrates are still found in high numbers on more floristically depauperate sites, food resources are still adequate to support Fat-tailed Dunnarts but may not be able to do so in the long term. Such sites may only provide an extension of marginal habitat from a core grassland area – an area which is used for foraging, but not as a permanent living site. Fat-tailed Dunnarts have been found to have a preference for loose scattered rocks in grassland remnants (Mathieson 1987). Rock piles in grassland areas did provide some habitat; however, those on agricultural land did not (Mathieson 1987). Areas with numerous, scattered rocks provide more potential nesting sites. Because the species tends not to be territorial, the presence of numerous scattered rocks may help in the migration of individuals between areas for both breeding and exploitation of available food resources (Morton 1978a, b, c). In this study, the Fat-tailed Dunnart was found living under stone walls and rock piles, and was observed using wolf spider holes on the Northern Plains. Micro-habitat use by this species at grasslands reflects the need for three important requirements:

1. open ground cover for actively foraging for invertebrate food items;
2. tussock cover for diurnal shelter and predator avoidance; and
3. floristic diversity.

Factors influencing abundance of the House Mouse

The relationship between habitat variables and the introduced House Mouse contrasted with the Fat-tailed Dunnart. House Mice are highly fecund and adaptable, and have been described as the ultimate mammalian 'weed' (Menkhorst 1995). They have exploited a wide range of habitat types across Australia. In natural vegetation, House Mice rely heavily on their ability to construct burrows or to shelter beneath rocks or logs, and their distribution is therefore largely determined by characteristics of the soil (Menkhorst 1995). The species has excellent dispersal and short-term colonising abilities and usually occupies unfilled niches (Braithwaite and Gullan 1978). It is a primary coloniser after disturbance but once vegetation is suitable for native mammal species, populations of House Mice rapidly decline. Numbers of House Mice on both the Western Basalt Plains and Northern Plains were higher on heavily grazed sites and on sites which were floristically poor. This supports the findings of Hadden and Westbrooke (1996), who found numbers of exotic species higher on more degraded, heavily grazed and weedy Buloke woodland sites. The Northern Plains sites with an open ground cover supported greater numbers of mice than sites with closed ground cover. On the Western Basalt Plains, sites that had a dense vegetation cover supported more individuals. It may be that, on the more intact grassland sites, the House Mouse is unable to compete effectively with the Fat-tailed Dunnart, while on more degraded and depauperate sites, the Fat-tailed Dunnart is less favoured, thus enabling the House Mouse to be the dominant species. Fox and Pople (1984) have stated that House Mice are apparently unable to compete successfully with small native mammals. Abramsky *et al.* (1979) reported that native mammals remained on natural short-grass prairie and only the exotic mammals occurred in completely modified areas.

Management implications

Conservation of native mammals

The Fat-tailed Dunnart was located across a range of grassland types of the Western Basalt Plains and Northern Plains. However, very few recaptures were made. It is not known if populations of Fat-tailed Dunnarts are secure on these grassland remnants. The Common Dunnart was recorded at one site on the Western Basalt Plains.

Given that this species is uncommon and has not previously been recorded in grassland vegetation, survey work to attempt to locate more individuals is warranted.

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How Do Nectar Foraging Butterflies Select Flowers?

Melissa B Nunn[1]

Abstract
Nectar foraging tendencies of two species of butterfly was experimentally investigated using characteristics of flowers that may influence selection of nectar resources. Potentially influential characteristics of nectar flowers were simulated in various combinations in a controlled laboratory situation. Wild-caught butterflies were captured for use in the experiments. The two species preferred different combinations of factors, potentially reflecting their natural foodplants. Common Grass-blue *Zizina labradus* visited small white flowers most frequently, a combination of factors displayed by known foodplants. Australian Painted Lady *Vanessa kershawi* preferred to feed on yellow, medium or large flower combinations that match the flowers of Capeweed *Arctotheca calendula* and some other observed foodplants. The position of the experimental flower on the 'stem' was not a significant contributor to flower selection; however, flower size did contribute. There was a positive relationship between the size of the butterfly and that of the flower chosen. In the wild, this may reflect not only the flower's ability to support the weight of the butterfly, but also the amount of nectar supplied by the flower. (*The Victorian Naturalist* **119** (1), 2002, 21-27)

Introduction

Butterflies are the most studied of the invertebrates, yet there is still much to discover about their ecology, behaviour and general biology. The focus of research is generally on rare or exotic species, and little information is known on the more common species (Kitching and Scheermeyer 1999).

Definitive studies of ecology and behaviour are lacking for common species such as Yellow Admiral *Vanessa itea*, Australian Painted Lady *Vanessa kershawi* and Common Grass-blue *Zizina labradus*, which occur frequently where this study was conducted.

Butterflies feed solely on a liquid diet consisting of plant nectar and sometimes water or other fluids (Braby 2000). The preferred source of nectar for butterflies is nectar-bearing flowers. The nectar that is produced by plants contains two of the most vital ingredients for obligatory feeders such as butterflies: carbohydrates and protein (Brackenbury 1995). Butterflies, with their specialised narrow tubular proboscis, are able to access carbohydrates and proteins contained in nectar by capillary action (CSIRO 1991).

Vanessa kershawi generally appears in late August and early September in the Ballarat region and is usually the first adult butterfly to be seen each season (G Ambrose pers. comm. 2000). *Zizina labradus* is more often found in gardens, lawns, pastures, and weedy areas than in bushland (Coupar and Coupar 1992). They are common in many suburban areas, including Ballarat.

Insects locate nectar-bearing flowers by means of visual cues rather than by smell or touch. The attraction is so powerful that butterflies will be attracted to flowers that are placed in an artificial setting. These visual cues attract the butterfly to the mouth of the corolla. Nectar guides (markings on flowers) provide a way of guiding the proboscis of the butterfly toward the nectaries (organs that secrete nectar). Nectar guides may reflect strongly in the ultraviolet section of the light spectrum in which butterflies are sensitive (Brackenbury 1995).

Ford (1985) has suggested that smaller nectarivorous bird species are more mobile than larger species and perch on flowers on the end of branches without breaking them. The smaller bird species are also more acrobatic and are able to hover above the flowers on the tips of the branches and feed. Butterflies may mirror this behaviour, whereby smaller butterflies may prefer flowers on the tips of stems.

It is documented that sometimes different butterfly species prefer different flowers (Clyne 2000; Braby 2000). However, over 100 species of butterflies feeding on Lantana *Lantana camara* have been observed, which suggests that butterflies may also be opportunistic. The aims of this

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study were to use artificial flowers to discover which characteristics of flowers attract two butterfly species, and to compare the findings to known foodplants and their characteristics. It was expected that the butterflies in the study would also prefer a particular group of flowers.

Methods

Preparation

Two butterfly species, *Vanessa kershawi* and *Zizina labradus*, were used in the examination of three important flower characteristics. These were chosen based on the literature (Brakenbury 1995; Coupar and Coupar 1992). These characteristics were size, colour and the position on the plant where flowers grow. Artificial plastic flowers were used and the sizes (small, medium and large) were scaled to known nectar source species from the daisy family Asteraceae. The artificial flowers were 2.5, 4.0 and 6.0 cm in diameter respectively. The paint colours chosen for the study included three that were common in the Ballarat region in September, namely white, yellow and purple. Two positions were chosen to represent flowers that grow close to the main trunk of the plant and flowers that grow on the tips of the plant.

A cage was constructed by modifying an old plywood finch cage. The sides and roof were cut out and replaced by fibreglass flywire, with the exception of one side that was draped with muslin. This enabled access to the inside of the cage and was knotted when not in use. The frame of the cage was painted white so that it provided a light coloured backdrop against which butterfly activity could be seen clearly.

The artificial flowers were drawn on icecream container lids in the shape of flowers from the Asteraceae family. These were then coloured with acrylic paints. Acrylic paints were used because they dry quickly, are odourless and non-toxic. They also do not run into the nectar solution on contact. Four millimetre plastic hose was sliced to produce thin plastic rings that acted as nectar cups. These were glued to the centre of the flowers with non-toxic glue. Three timber frames were constructed to hold the flowers and to simulate positions on a plant where the flowers might grow. The design of the timber frame used in the study is shown in Fig. 1. Small nails were used to hold the flowers to the frames and the glue used on the nectar cups was used to seal the centres of the flowers against leakage of nectar. Yellow cotton wool was then packed tightly into the nectar cups to absorb the nectar, preventing drowning of the butterflies whilst still allowing access.

Nectar

Artificial nectar was produced using a recipe used at Melbourne Zoo's Butterfly House. The nectar used in this study and in a study conducted by Harris (1993) contained approximately 15 percent sugars. The recipe (see below) was halved to make one litre of nectar. This formula makes enough nectar to feed about 800 butterflies for 24 hours.

The recipe used by the Melbourne Zoo's butterfly house comprises 500 ml of purified water (boiled), with 130 g of sucrose and 95 g of glucose or dextrose added and stirred until they were dissolved. 200 g of liquefied fructose (approximately 130 g when crystallised) were added and stirred in until dissolved. 500 ml of cold purified water and half a teaspoon of honey were added and the solution and stirred. Cold purified water was added to take the quantity up to two litres.

The different types of sugars are from various plant sources, each supplying different molecular structures and nutrients.

Fig. 1. The design of the timber frame on which the artificial flowers were placed during the study. The base and main trunk were made of 25 mm × 19 mm pine painted green. The three branches were made from dowel 10 mm in diameter. The dowel represents the branch of a plant and the flower placed closer to the centre of the dowel represents flowers close to the trunk.

The addition of honey is thought to be the vital ingredient that provides the butterflies with the essential nutrients that can sustain them over a long period. Honey contains Vitamin C, protein and small quantities of nitrogenous compounds, minerals, organic acids and lipids (Winston 1987). The butterflies at the Melbourne Zoo spend their entire lives on this formula.

Capture of butterflies

Butterflies were captured on sunny days in early September when they first began to emerge. Optimal capture numbers were on days that had followed one or two fine, warm days. The capture sites included gardens in town and an open area on the Ballarat University campus at Mount Helen that has both native and exotic vegetation. An insect net was used to capture the butterflies. Undamaged specimens were retained and put into a container with a muslin insert in the lid. The butterflies were not fed for 48 hr before any sampling to encourage hunger. Sixty-seven individuals were captured during the study, 35 of which were *V. kershawi* and 31 *Z. labradus.*

Foraging observations

Observations were undertaken on four occasions, 48 hours after capture. The study cage was placed in a glasshouse that provided a warm and humid environment, which encouraged butterfly activity. The glasshouse was connected to a thermostat, which was kept at around 25°C. Each observation period took one hour, which was the optimum time discovered from a pilot study. One hour was enough time for each butterfly to feed three or four times and was brief enough to allow the nectar to stay moist.

Data analysis

Data were analysed using the software package SPSS 10 for Windows. Univariate ANOVA test was used to test for significance between the categories of data (Coakes and Steed 2001; Kitchens 1998). The ANOVA statistic is used to examine the difference between the means of foraging frequencies for the two species, and to determine whether they are significantly different. Profile plots and ANOVA were used to see if there were any interactions between the characteristics studied.

Limitations

Other variables or characteristics that may influence the frequency of visits such as nectar volume, shape of flower and ultraviolet reflectivity were not tested. The brief nature of the study limited the number of variables that could be tested. It was decided only to test what were thought to be the most influential factors including size, colour and position, allowing these variables to be thoroughly examined in the time allocated.

All taxonomic names in this paper follow that of Braby (2000) for butterflies and Ross (2000) for vascular plants.

Results

The flower characteristics preferred by each butterfly species are shown in Figs 2, 3 and 4. *Vanessa kershawi* visited yellow flowers more often than white or purple flowers. Response to colour itself, when tested for both species, showed no significant difference of frequencies compared to the other factors ($F = 5.907$, $p = 0.064$). This indicates that there was no particular colour preference overall for both species. There was, however, a colour-species interaction evident, which indicates that each species tended to prefer a particular colour ($F = 9.559$, $p = 0.030$).

The majority of flowers visited by *V. kershawi* were large or medium in size. As shown in Fig. 4, *V. kershawi* also tended to visit flowers that were positioned close to the trunk of the plant more often than those positioned on the tips of the branches. However, there was no significant difference found between the use of the two positions on the plant ($F = 1.113$, $p = 0.402$).

Zizina labradus significantly favoured white flowers ($F = 9.559$, $p = 0.030$; Fig. 3), with the purple and yellow flowers being less frequently visited. There was also a significant preference for small flowers ($F = 8.72$, $p = 0.041$), with the medium and large flowers much less often visited (Fig. 2). There appeared to be a slight preference for flowers positioned on the tips of the branches, but the difference was not significant ($F = 3.692$, $p = 0.195$).

Vanessa kershawi tended to visit medium sized yellow flowers that were positioned on the trunk more frequently than any

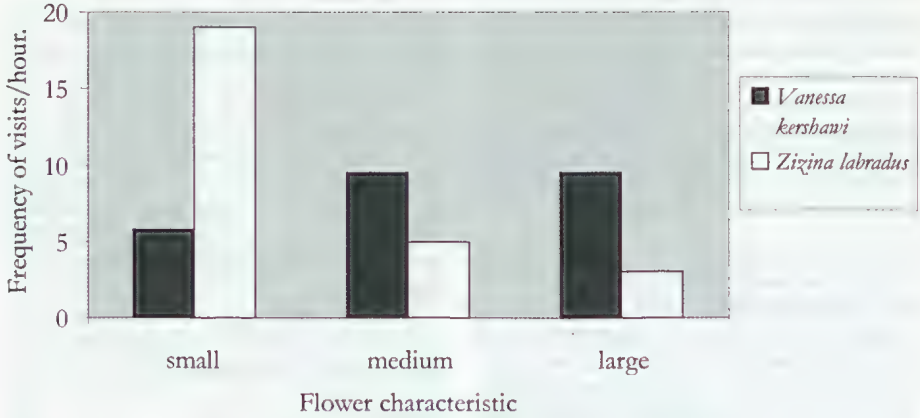

Fig. 2. Frequency of visits for *Vanessa kershawi and Zizina labradus* with respect to flower size.

Fig. 3. Frequency of visits for *Vanessa kershawi and Zizina labradus* with respect to colour of flower.

other combination of characteristics (Table 1). Flowers that were not visited at all included large purple trunk, small white trunk and medium white branch flowers. *Zizina labradus* tended to visit small, white flowers (Table 2). Use of the two small white combinations were significantly different from the other combinations. The flowers that were not visited at all were the purple, medium and large flowers positioned on the branch.

The characteristics that had the strongest association with visiting frequency were the colour and size of the flower. This suggests that each species has a preference for particular characteristics in these groups of factors. This is also evident from Figs 2 and 3. The position of the flower on the plant had little influence on visit frequency.

Discussion

Vanessa kershawi visited yellow flowers most often. These flowers were mostly medium or large. It is evident that flowers with combinations of traits that *V. kershawi* was observed to feed on in this study may match such species as Capeweed *Arctotheca calendula,* Daisies *Euryops* sp. and Everlasting Daisies *Bracteantha* sp. Low (2000) details some butterfly species found to have fed on such species of food-plants. Foliage of these plants is also eaten

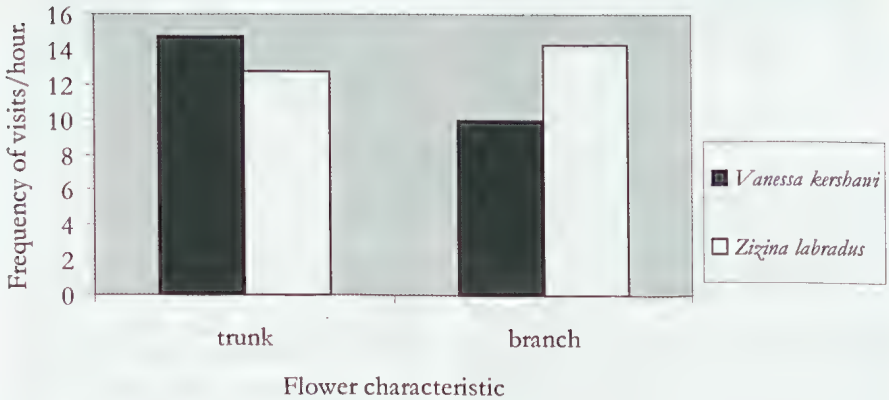

Fig. 4 Frequency of visits for *Vanessa kershawi* and *Zizina labradus* with respect to flower position.

by the butterfly's larval stages (Braby 2000). Smooth Cats Ear *Hypochoeris glabra* and Hairy Hawkbit *Leontodon taraxacoides* are also abundant introduced yellow flowered daisies in the region. They flower over many months and are commonly visited by *V. kershawi* for nectar (G Arnbrose pers. comm. 2000). Capeweed is a weed of agricultural areas and is more often encountered by butterflies (Low 2000) near Ballarat than their native larval hostplants, members of the family Asteraceae.

Zizina labradus showed a significant preference for white flowers. This agrees with the reports by Clyne (2000) and Common and Waterhouse (1972) of butterflies feeding on flowers with similar characteristics. Such flowers include Lawn Daisy *Bellis perennis*, Clover *Trifolium subterraneum* and native peas. The size of these flowers is similar to that of the small flower in this study, which could explain the preference for small flowers. Small, white flowers were the most visited of all the combinations, and were significantly different from the other combinations, although not from each other. This indicates that there is no preference by *Zizina labradus* to the positioning of flowers on the trunk or branch.

Vanessa kershawi visited large and medium flowers with a slight but not significant preference for the trunk. G Ambrose, (2000 pers. comm.) suggests that flowers that are pollinated by small butterflies may not be able to support the weight of larger butterflies. Therefore the larger of these two butterflies may find the larger flowers offer a more stable support when feeding.

Main (1981) suggests that the larger the flower, generally the more nectar it produces, and that bigger flowers can support larger birds both by the quantity of nectar and by the strength of the flower. This can also be applied to butterflies. Larger flowers usually have a larger nectar reward than smaller flowers, making them more attractive to larger species of nectar foraging fauna (Paton 1985). However, Dunn (1999) lists several very large butterflies feeding on small flowers of Lantana, and highlights a low yield of nectar per flower. The larger butterfly would need more energy to sustain itself; it would therefore tend to visit the flowers that were more likely to contain larger rewards in a field situation.

The body size of *V. kershawi* was much larger than the small flowers in the study. The results suggested that the bigger the flower, the more likely it was to be visited on the trunk. Under normal circumstances, a larger flower with sturdier support would offer these butterflies a more stable feeding platform (Main 1981).

There may be two possible explanations for the feeding patterns observed in this study. Thompson (1999) suggests that butterflies tend to be specialised in their choice of nectar and host plant. This suggests that they may be predisposed to

Table 1. The number of visits per hour made by *Vanessa kershawi* to each flower combination.

Colour	Size	Trunk	Branch
yellow	s	1.5	2.25
	m	5.25	2.25
	l	4.25	2.75
purple	s	1.25	0.25
	m	0.25	0.75
	l	0	1
white	s	0	0.5
	m	1	0
	l	1.25	0.25

Table 2. The number of visits per hour made by *Zizina labradus* to each flower combination.

Colour	Size	Trunk	Branch
yellow	s	2.25	2.5
	m	1	0.75
	l	0.75	0.25
purple	s	1	2.25
	m	0.75	0
	l	0.75	0
white	s	5.25	5.75
	m	1	1.5
	l	0.25	1.25

select the flower types or characteristics that optimise their foraging efficiency. As the preferences for natural hostplants match the preferences of the flowers in the study, it may be likely that these recorded preferences are adaptive for the butterfly species used in this study.

When foraging for nectar, butterflies sometimes exhibit constancy (preference for a particular species previously visited) and often ignore rewarding flowers of different species (Goulsen *et al.* 1997). Nectar rewards were constant for all flowers during this experiment and so did not contribute to the observed differences in foraging frequencies. Darwin (1859) described how the learning of handling skills by a butterfly for one flower interferes with the learning of handling skills for another. Handling skills are skills that a butterfly has had to learn to feed from a flower. For example, a butterfly may have to perform mid-flight 'acrobatics' to feed from a particular tubular flower, or must land on a certain area of another flower to avoid falling off. The butterflies possibly visited flowers similar to those with which they were familiar and did not need to learn such handling skills, in the short time of the study.

The reflectivity of the paint on the flowers was not tested in this study. The effect of ultraviolet reflectivity of the flowers on frequency of visits is not known. However, it is known that visual cues are used to attract butterflies to flowers (Brackenbury 1995). Colouration of the artificial flowers was simple, without any ultraviolet patterning. Nectar guides were not provided nor were patterns that may be visible on flowers under ultraviolet light. *Zizina labradus* visits purple flowers in the wild, including those of *Cullen*, *Hardenbergia* and *Hovea* spp., which may or may not have ultraviolet patterning (Clarke and Lee 1987).

The methods used were novel and improvised because there has been limited study in this area. There has been no benchmark method for this particular area of research and methods were chosen according to their expected suitability. Other variables may contribute to the selection of nectar plants, such as the time of day, size and type of nectar reward, shape of flower, ultraviolet reflectivity and possibly pollen volume. Further study should endeavour to answer these questions.

Conclusion

Vanessa kershawi and Zizina labradus prefer flowers that exhibit a different combination of characteristics. The characteristics preferred by *V. kershawi* include yellow, medium or large flowers and *Z. labradus*, white, small flowers. These combinations of characteristics tend to match those of the butterflies' known foodplants.

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Hooded Plover *Thinornis rubricollis* Chick Attacked by Conspecifics

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We report an observation of adult Hooded Plovers *Thinornis rubricollis* attacking a flightless chick at Mornington Peninsula National Park. The chick was not seen again, and apparently did not survive to fly, although it is not known whether the attacks contributed to its presumed death. Causes of mortality in Hooded Plover chicks are poorly known, although mortality rates are high (Weston 1998a, 2000). The eastern population of this species is threatened, and is classified as Vulnerable (Garnett and Crowley 2000). Consequently, any observations of the dangers that chicks may encounter are noteworthy.

On 30 December 2000 one of us (VT) was conducting a foot patrol along the ocean beaches in the Mornington Peninsula National Park, between Sorrento and Portsea, Victoria. At the Franklin Road access track (38°20' S, 144°43' E), at Portsea, a pair of adults attending a young chick was observed (the chick was between 17 and 24 days old). This area is used by flocks in winter, and by small flocks during the breeding season (B Dowling pers. comm.). A group of six adults was close to the pair and chick. The pair attending the chick was aggressive towards the nearby flock, and a number of short aerial chases were observed. In the

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confusion, the chick was temporarily separated from its defending parents. Adults from the flock ran directly at the chick, and the chick ran away from them. Adults from the flock also began 'dive-bombing' the chick by flying low and directly at it. About four such 'dive-bombs' occurred, and the chick was struck twice. The chick fell over on each occasion, and each strike caused feathers to be dislodged from the chick. Each time the chick was struck the attacking adult landed and chased it on foot until a parent intervened. During these attacks the chick piped continuously.

It seemed that the attacks would continue, so when three adults from the flock aggressively approached the chick, VT intervened in order to give the chick a chance to find shelter (these birds were part of an intensively managed population; see Dowling and Weston 1999). The chick managed to hide. It was evident that the aggression continued between the parents and the flock after observations ceased. Although the parents were seen on two subsequent visits (on 5 January 2001 and 18 January 2001), the chick apparently did not survive to fledge as it was not seen again.

No other reports of such aggression to chicks are known to us (Marchant and Higgins 1993). Weston (2000) observed broods for more than 270 hours and never recorded any such attacks. In an intensive 9-year study in the National Park, no such attacks have been recorded until now (Dowling and Weston 1999; B Dowling and M Urquhart pers. comms). The aggressive defence by the parents is common; brood-rearing parents repel intruding conspecifics vigorously, with one observation of a parent 'dive-bombing' and striking an intruding adult (Weston 1998b).

The cause of this aggression is unknown, but we speculate that displacement of the flock occurred, such that territorial aggression escalated to the point where the chick was attacked. The pair had been in the area since 23 November 2000, and in early December a Temporary Beach Closure had been implemented, so the territory seemed spatially stable. Observations of colour-banded birds have shown that birds in flocks consist of non-breeders and sometimes include off-duty, and presumably territorial, breeding birds (MAW pers. obs.). The observations occurred on a busy Saturday, and so recreationists (or VT) may have displaced the birds, and caused them to concentrate into one area. Disturbance by humans displaces some birds, including those with broods (Hockin *et al.* 1992; Brown and Morris 1995; Hill *et al.* 1997; Lord *et al.* 1997). Displacement of breeding Black Skimmers *Rynchops niger* to nearby less-disturbed areas has caused nesting density to increase, and this may have caused an increased number of territorial disputes which could compromise the survival of chicks (Safina and Burger 1983). A similar displacement, albeit over a shorter timespan, may have lead to the extreme aggression reported here.

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Invertebrates of Mount McKay – a Brief Survey

EJ Grey[1]

Abstract
This note reports the results of a brief, small-scale survey of terrestrial invertebrates near Mount McKay in north-east Victoria conducted in October 1999. Survey areas, in this sub-alpine zone, included Open Heathland, Tussock Grassland and small Snow Gum *Eucalyptus pauciflora* patches. The invertebrates were collected in pitfall traps and by hand and the greatest numbers were taken in the more open sites that were exposed to sunshine. (*The Victorian Naturalist* **119** (1), 2002, 29-35)

Introduction

A combined Field Naturalists Club of Victoria and Victorian National Parks Association expedition to Mount McKay was held over the period 29 October-2 November 1999. The purpose was to increase appreciation and knowledge of the ecology, geology, flora and fauna of the area in view of its proposed excision from the Alpine National Park, a decision that has since been rescinded (Parliament of Victoria 2001).

A small-scale survey of terrestrial invertebrate fauna was undertaken as part of the expedition. Two sites were sampled by pitfall trapping, and direct hand collecting was carried out over several areas around Mount McKay.

At the time of the expedition, invertebrate activity would have just started to increase after the winter months. From this point of view a later time, perhaps January, would have produced greater numbers (Green 1997).

A short search of the literature indicated there were few studies of ground dwelling invertebrates of the Australian high country. The most comprehensive general discussion of invertebrates in these areas is by Green and Osborne (1994), while Green (1997) details survey results from pitfall trapping over a lengthy period in the Snowy Mountains, particularly emphasising the seasonal and altitudinal variations. Osborne *et al.* (1978) listed invertebrates collected from the snow surface in Kosciusko National Park and Green (1982) reported the results of pitfall trapping beneath the snow, from the same area.

A survey of 'sub-alpine woodland' conducted in 1973/1974 in Victoria listed 51 invertebrate families from 7 orders (Land Conservation Council 1977), and Swarbrick (1946) gives notes on some of the 50 species of insects collected by hand at Mt Buffalo over a period of two weeks.

Methods

Mount McKay forms part of the Bogong High Plains in the Victorian High Country and lies approximately 2 km south of Falls Creek Village. Vegetation varies from Open Heathland through Closed Heathland to Tussock Grassland with small patches of Snow Gums. Rocky outcrops are also a feature.

The two sites chosen for pitfall trapping each comprised three distinct vegetation types:

1. Snow Gum *Eucalyptus pauciflora* patches with exposed granite outcrops. Open Heath species also occurred with grassy, open spaces between shrubs.
2. Open Heath with *Phebalium squamulosum* subsp. *alpinum* (in flower) and Mountain Beard Heath *Leucopogon hookeri*. Other species most likely present but not identified would have included *Grevillea australis*, Alpine Hovea *Hovea montana*, and Alpine Orites *Orites lancifolia* (Bogong High Plains, Vegetation Map and Guide to Alpine Flora, Pretty Valley Sheet);
3. Tussock Grassland with Soft Snow Grass *Poa hiemata* and *Ranunculus* sp. (in flower) (Bogong High Plains Vegetation Map and Guide to Alpine Flora; Willis *et al.* 1975).

The two sites were located near access roads to the east of Mount Mckay and both had elevations c. 1500 m ASL. The first site established (site A in this article) was located at 36°52'38" S 147°14'45" E, and the second (site B) at 36°52'54" S 147°15'01"E. At each site, the three distinct habitat types

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were a short distance apart, separated by some 20-30 m and with little difference in altitude.

Direct hand collecting was done at a number of areas around the vicinity of Mount McKay. The results section records where the specimens were found.

At the pitfall trapping sites A and B, three lines of six traps were set with one line in each habitat type. Each line was numbered: 1, Snow Gum patch; 2, Open Heathland; 3, Tussock Grassland. Plastic coffee cups of 200 ml capacity, height 80 mm and top diameter 72 mm were used for the traps. Each trap was dug in flush with the ground and 30 ml of preserving fluid was placed in each. The preserving fluid was a 50/50 mixture of ethylene glycol and 70% ethanol. The pitfall traps were open for four days from 28 October (the day they were dug in) to 1 November 1999. The weather during this period was variable with cool, sunny days, one night with severe frost, and some rain. A maximum/minimum thermometer and a rain gauge were set up at Site A. The thermometer was suspended from a Snow Gum branch, and the rain gauge was attached to a star picket. Over the sampling period, the recorded shade temperature range was –3° to +13°C and 40 mm of rain fell. The weather observations for Site A were assumed to apply to Site B as the sites were less than one kilometre apart, had westerly aspects and were roughly at the same elevation.

For comparison, weather data for the months of October and November 1999 were obtained from the Bureau of Meteorology for Mt Hotham, the nearest recording site (Table 1). Mt Hotham is situated c. 15 km south-west of Mt McKay and has an elevation of 1849 m, which is approximately 350 m higher than the site at Mt McKay.

Hand collection was carried out at random and no attempt was made to regulate the time spent in this activity, or the number of people involved. Invertebrates were collected from vegetation, under rocks and from streams, and each person kept a note of the habitat for each sample.

At a later date, identification of ants was to genus (species or species group where possible); beetles and spiders to family level, and all other invertebrates to order (sometimes class or phylum). The keys used for identification included: ants (Andersen 1991; Greenslade 1979; Shattuck 1999); beetles (Moore 1980); spiders (Davies 1986); and all other invertebrates (Harvey and Yen 1989).

Table 1. Mt Hotham Weather Station. Data for October and November 1999.

	Oct 1999	Nov 1999
Mean daily maximum temperature °C	8.0	8.1
Mean daily minimum temperature °C	1.8	1.4
Highest temperature °C	15.6	15.4
Lowest temperature °C	-5.4	-6.5
Mean monthly rainfall mm	29.2	137.6

Results

The material trapped in each of the six traps per line was pooled to give one sample for that site, e.g. A1 contains all material from the six traps in the Snow Gum patch at Site A. Table 2 is a list of the total numbers of invertebrates per pitfall trap line.

The most numerous groups were found in 'Other orders', and while Flies (Diptera) made up most of the numbers, Springtails (Collembola) were very abundant at site B1 with an estimated number of 10,000 individuals (see note in Table 6).

The numbers of Ants (Hymenoptera) caught in the pitfall traps are shown in Table 3. The ants were identified to genus (indicated as sp.), to species group (as shown by species in inverted commas) or, in some cases, to species.

A total of eight genera from four subfamilies was recorded from the pitfall traps. The largest number were from the Dolichoderinae (92%) with one species group *Anonychomyrma 'itinerans'* making up 96% of the sub-family.

The Dolichoderinae are generalist predators and favoured the Open Heath and Tussock Grassland habitats. These ants are characteristic of open and sunny places (Andersen 1991). However, the large numbers found in the Tussock Grassland (site A3) may be associated with a large nest (or nests) or a foraging trail. Shattuck (1999) notes that nest sizes for *Anonychomyrma*

Table 2. Total numbers of invertebrates collected in pitfall traps.

Habitat	Snow Gum Patch		Open Heath		Tussock Grassland	
Site	A1	B1	A2	B2	A3	B3
Ants (Hymenoptera)	18	7	52	40	259	5
Beetles (Coleoptera)	19	13	40	33	23	15
Spiders (Araneae)	5	4	17	3	20	15
Other Orders	285	10,293	367	500	267	324

Table 3. Total ants (Hymenoptera:Formicidae) in the pitfall traps.

Habitat	Snow Gum Patch		Open Heath		Tussock Grassland	
Site	A1	B1	A2	B2	A3	B3
Myrmicinae						
Aphaenogaster sp.	-	-	-	2	-	-
Monomorium sp.	-	5	-	-	-	-
Pheidole sp.	6	-	-	7	-	-
Ponerinae						
Amblyopone australis	-	-	-	-	-	1
Dolichoderinae						
Anonychomyrma 'itinerans'	-	-	52	23	259	4
Iridomyrmex sp.	12	-	-	-	-	-
Formicinae						
Plagiolepsis sp.	-	1	-	-	-	-
Prolasius sp.	-	1	-	8	-	-

'itinerans' range from 500 to tens of thousands of workers.

The maximum temperature of 13°C recorded during the survey is at the lower level for ant functioning with 10°C being the limit for any functioning at all (Hölldobler and Wilson 1990, 1994). Therefore, the two Dolichoderinae genera must have adapted to foraging in these cool conditions, although the temperatures at the ground surface and certainly within the nest would have been higher than the shade temperatures measured. On the other hand, specialist cool climate ants, in this case *Monomorium*, *Plagiolepsis* and *Prolasius*, were not notably abundant in this survey (Andersen 1990).

Table 4 lists the beetles (Coleoptera) found in the pitfall traps. Identification was to family level. However, the key used (Moore 1980) was not applicable for beetles smaller than 3 mm, and so were classed as 'undetermined' specimens.

The beetle families found in this survey can be divided into two main groups. The first group is those adults and larvae that rely on living prey or carrion for food. These are the predators – the Ground Beetles (Carabidae), Pselaphidae and Rove Beetles (Staphylinidae) – and are the most numerous group, making up 69% of the total number of beetles collected. The Ground Beetles were the most abundant family and most were found in the Open Heath and Tussock Grassland. These beetles (and their larvae) feed on smaller and weaker insects as well as on larvae of other invertebrates. They use their strong jaws for seizing, tearing and crushing their victims (Hawkeswood 1987).

The second group is the herbivores, which encompass those that, as adults or larvae, feed on living, as well as dead or decaying plant material – Longicorn Beetles (Cerambycidae), Leaf Beetles (Chrysomelidae) and Weevils (Curculionidae).

Click Beetles (Elateridae) can be included in both groups since larvae of some members of this family are plant feeders while others eat insect larvae (Mathews 1985).

Pitfall trapping favours the ground dwelling families, hence larger numbers of Ground Beetles, Rove Beetles and Weevils (Green and Osborne 1994).

The greatest spider abundance came from the Open Heath and Tussock Grassland habitats. Most of the spiders caught in the pitfall traps were from ground-dwelling families and this reflects the method used

Table 4. Total beetles (Coleoptera) in the pitfall traps.

Habitat	Snow Gum Patch		Open Heath		Tussock Grassland	
Site	A1	B1	A2	B2	A3	B3
Family						
Carabidae (Ground Beetles)	5	6	31	26	17	5
Cerambycidae (Longhorn Beetles)	4	-	1	-	-	-
Chrysomelidae (Leaf Beetles)	-	1	-	-	-	3
Curculionidae (Weevils)	-	3	6	6	1	3
Elateridae (Click Beetles)	-	1	-	1	-	-
Pselaphidae	-	-	-	-	-	2
Staphylinidae (Rove Beetles)	5	2	-	-	-	-
Undetermined	5	-	2	-	5	2

Table 5. Total spiders (Araneae) in the pitfall traps.

Habitat		Snow Gum Patch		Open Heath		Tussock Grassland	
Site		A1	B1	A2	B2	A3	B3
Family							
Mygalomorphae	Hexathelidae	-	-	-	1	-	-
	Nemesiidae	2	-	-	-	-	-
Araneomorphae	Gnaphosidae	-	-	10	-	-	1
	Hadrotarsidae	-	-	-	-	1	-
	Lycosidae (Wolf Spider)	-	2	7	2	1	6
	Miturgidae	3	2	-	-	18	8

for sampling. Spiders that spend their lives above ground level – the web builders and other foliage-dwelling species – are unlikely to be found in pitfall traps. Table 5 lists, in families, the spiders found.

Three families, the Gnaphosidae, Miturgidae and Lycosidae, comprised the bulk of the specimens. All of these families are active, open-range hunters preying on a variety of invertebrate fauna including crickets, locusts and other spiders (Brunet 1996).

The single member of the Hexathelidae comes from the family that includes the Sydney Funnel Web spider, but our specimen is not this species.

Table 6 gives an indication of the variety of invertebrate fauna found by pitfall trapping. Only adults from all the orders were found in the traps, and larvae were noticeably absent. Most of the material was identified to order level, although one centipede could only be identified to class.

The flies (Diptera) and mites (Acarina) were the most abundant orders, although at one site in the Snow Gum Patch habitat an estimated 10,000 springtails (Collembola) were collected. Mites and Collembola have both been recorded in large numbers in alpine areas (Green and Osborne 1994; McKeown 1942) and possibly the rain at the time of the survey influenced the numbers of Collembola from site B1.

The large number of flies (Diptera) are difficult to explain, although the cold to cool weather may have inhibited their flying and kept them on the ground.

Although opportunistic and unregulated, hand collecting (from foliage, under litter and rocks, and in one case from a stream), discovered members of the orders shown in Table 7.

The Wolf Spider (Lycosidae) was teased from its burrow with a grass stem, the burrow sealed with a knife and the spider captured on the ground surface.

Further observations

One interesting observation was the number of mating pairs of the Mountain Spotted Grasshopper *Monistria concinna* that were seen on roads and in the bush while inspecting pit-fall traps and during hand collecting. These are large grasshoppers with bright yellow spots on the body and a pale streak extending from the body to under the eye. The female is nearly double the length of the male and both are 'brachypterous', i.e. lacking functional wings (Green and Osborne 1994). The

Table 6. Total 'other invertebrates' in the pitfall traps.

Habitat	Snow Gum Patch		Open Heath		Tussock Grassland	
Site	A1	B1	A2	B2	A3	B3
Order/Phylum						
Acarina (Mites)	42	4	27	28	59	2
Amphipoda (Amphipods)	6	18	3	9	11	3
Phylum - Annelida (Worms)	-	-	2	-	-	-
Blattodea (Cockroaches)	1	1	1	1	-	-
Class - Chilopoda (Centipedes)	-	-	1	-	-	-
Lithobiida (Centipedes)	1	1	1	1	-	1
Collembola (Springtails)	4	10,000*	3	11	2	3
Diplura (Diplurans)	-	2	-	-	-	-
Diptera (Flies)	205	249	314	390	173	294
Haplotaxida (Earthworms)	1	2	-	1	-	7
Hemiptera (Bugs)	3	5	13	20	21	12
Hymenoptera (Wasps, Bees)	2	1	-	4	-	-
Isopoda (Slaters)	-	2	-	-	-	-
Opilionida (Harvestmen)	3	6	1	28	1	-
Orthoptera (Grasshoppers)	8	-	1	-	-	-
Platyhelminthes (Flatworms)	1	-	-	-	-	-
Polydesmida (Millipedes)	-	-	-	3	-	-
Polyzoniida (Millipedes)	-	2	-	-	-	-
Sphaerotheriida (Millipedes)	4	-	-	-	-	-
Symphyla (Symphylans)	-	-	-	3	-	-
Undetermined	4	-	-	1	-	2

* estimated by counting a fraction of the sample and multiplying to arrive at an approximate total.

Mountain Spotted Grasshopper has the ability to overwinter at any stage of development from the third instar to adult by entering diapause. This is the reason for such an early appearance of adult Mountain Spotted Grasshoppers and their mating at this time.

Another part of our work took us into sphagnum bogs in Pretty Valley at the headwaters of Pretty Valley Creek. Here we noticed two types of terrestrial invertebrates living in a wet environment. The first was the presence in the sphagnum beds of a number of spider holes, which were 30-40 mm diameter and closed with a dome-shaped web. These were taken to be the retreats of Wolf Spiders (Lycosidae), and Main (1984) notes that 'some species occur in bogs'. The only other likely spider family to be found in this situation would be the Water Spiders (Pisauridae) and, in particular, the genus *Dolomedes*. However, these spiders do not build a retreat or burrow (Main 1984).

The second was the surprising presence of many ant nests in the bogs. These consisted of mounds constructed of vegetation fragments, largely sphagnum moss, that were raised above the water level. Mounds are usually built as an aid to regulating the colony temperature and moderating extremes, an advantage in this situation (Hölldobler and Wilson 1990). These ants were members of the genus *Iridomyrmex* (sub-family Dolichoderinae), a large genus noted for occupying both 'the driest and the wettest of snow country environments' (Green and Osborne 1994).

It is interesting to note that the ant species from the Dolichoderinae found in the pitfall traps did not appear to have built mounds as none was sighted and they are normally quite visible.

Discussion

In spite of the cool weather and early (for invertebrates) season, a variety of invertebrates from 25 orders were recorded in this brief survey. Thus, the indication is that a rich and diverse invertebrate fauna inhabits this area. Further detailed surveys over longer periods and including summer would be necessary before firm conclusions can be made about the invertebrate fauna of Mt McKay.

The results of a survey of invertebrates from a low sub-alpine (1680 m ASL) site in the Snowy Mountains were given in

Table 7. Specimens caught from hand collection. Habitat key: UR, under rock; OV, on vegetation; RS, at road-side; IC, in cascade; OH, open heath; FB, from burrow.

Order	Family	Genus/Species Group/Species	Habitat/Location UR	OV	RS	IC	OH	FB
Amphipoda			-	-	-	1	-	-
Araneae	Araneidae		-	1	-	-	-	-
	Gnaphosidae		1	-	-	-	-	-
	Lycosidae		-	-	-	-	-	1
	Micopholcommatidae		1	-	-	-	-	-
	Miturgidae		-	2	-	-	-	-
	Nicodamidae		1	-	-	-	-	-
	Symphytognathidae		-	1	-	-	-	-
	Zodariidae		-	-	1	-	-	-
Blattodea			4	2	1	-	-	-
Coleoptera	Carabidae		6	-	-	-	-	-
	Chrysomeledae		-	1	-	-	-	-
	Curculionidae		1	-	-	-	-	-
	Tenebrionidae		1	-	-	-	-	-
Diptera			-	1	-	-	-	-
Ephemeroptera (larva)			-	-	-	1	-	-
Hymenoptera	Formicidae	*Amblyopone*	10	-	-	-	-	-
		Hypoponera	1	-	-	-	-	-
		Anonychomyrma 'itinerans'	9	-	-	-	13	-
		Myrmecia pilosula	-	-	-	-	7	-
Isopoda			1	-	-	-	-	-
Odonata (nymphal case)			-	1	-	-	-	-
Orthoptera			-	6	-	-	-	-
Hemiptera			-	3	-	-	-	-
Plecoptera (larva)			-	-	-	1	-	-
Polydesmida			-	1	-	-	-	-

Green (1997). Table 8 compares the results, for selected groups, from this study with those from the work at Mt McKay. It is interesting that the two sets of results are quite comparable, despite the difference in total numbers, and emphasise the influence of Collembola on invertebrate fauna composition in these areas.

One interesting question that further work on ants might answer is why in this survey there was a virtual absence of cold climate specialists species (*Monomorium* spp., *Notoncus* spp. and *Prolasius* spp.). From previous studies (Andersen 1990) these would have been expected to make up a substantial proportion of the ant fauna.

Another point relating to ants which requires further work is to understand how the ant communities are interrelated at Mt McKay. Other work has indicated that Dolichoderinae species, which include *Anonychomyrma* and *Iridomyrmex*, play a less dominant role and are less abundant in cooler climate communities (Andersen 1990). In these communities, cold climate species and opportunists such as *Rhytidoponera* spp. and *Paratrechina* spp. are the most common ants. The results from this survey do not bear this out and possibly a different community organisation exists at Mt McKay where Dolichoderinae were found to be the most abundant family.

Table 8. Comparative results from two invertebrate studies shown as percentage contribution by numbers for selected groups.

	% Contribution	
	Low sub-alpine area (Green 1997)	**Mt McKay (1999)**
Coleoptera	1.3	1.1
Hymenoptera	2.1	3.0
Araneae	1.8	0.5
Collembola	80.1	79.4
Diptera	9.6	12.9
Acarina	1.1	1.3
Total	**1,068**	**12,616**

The results of this limited survey give some indication that the Mt McKay habitat

is relatively undisturbed because of the absence of opportunistic ant species that are characteristic of disturbed areas (Andersen 1990). However, additional work on this point is also needed.

Acknowledgements
The collecting was done under Flora and Fauna Permit Number 10000715. Thanks are due to members of the Field Naturalists Club of Victoria and Victorian National Parks Association who helped with the fieldwork and subsequent identification, and to Ian Bell for providing weather bureau data. Special thanks go to Erich and Elsbeth Sacco and Patricia Grey for their assistance in setting up the pit-fall lines. An early draft of this article was much improved by the comments of an anonymous referee.

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Vale Alexander Clifford Beauglehole OAM

Club members will be saddened to learn of the death of Cliff Beauglehole in January 2002. Cliff made enormous contributions to our knowledge of the distribution and conservation of Victorian plants. He was also a recipient of the Australian Natural History Medallion. A tribute to Cliff will appear in a later issue.

For assistance with the preparation of this issue, thanks to Karen Dobson (label printing), Dorothy Mahler (administrative assistance) and Phil Bock (web page).

The Biodiversity Blitz

There is something very satisfying about seeing a group of experts in their own fields enthused by being together with like-minded people, their only task to go out and explore. This was the scene at Kosciuszko National Park on the weekend of 12-13 January when a 'Biodiversity Blitz' was held over 24 hours. It was the first major event held in Australia to celebrate the International Year of Mountains. The concept of a Biodiversity Blitz originated in Germany, where it is a common event, and spread to Switzerland in 2000, where it was sponsored by the German journal *Geo*. The task is to document every species of living thing within a defined area over a 24 hour period. The Swiss event 'Alp Blix' was held near Chur and was organised by Jürg Müller from the Natural History Museum at Chur (well worth a visit!). I arrived at Chur after the event but the continuing enthusiasm of Jürg and the results published in full colour in 'Geo' sparked my interest.

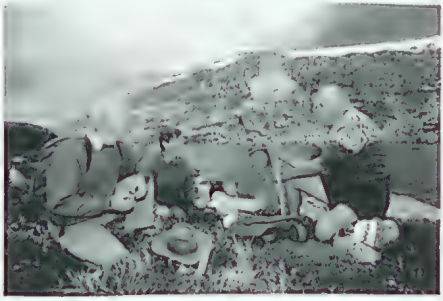
Because we needed accommodation and because it is the International Year of Mountains, the blitz was set up to look at the biodiversity between our accommodation at Thredbo at 1400 m altitude and the summit of Mt Kosciuzsko at 2228 m – a total of 27 square kilometres, rather big but at least it had something for everybody. Getting so many experts together in one place for one weekend involved a lot of organisation, not made easier as the date approached by the fires that started in NSW around Christmas and took myself and most of the local National Parks and Wildlife Service staff out of the running for a good part of the time. There were logistical problems too; how to find a punt and then get it onto Australia's highest water body – Lake Cootapatamba. Victoria's Department of Natural Resources and Environment solved the first problem and Brian Timms, who has worked on the lakes for many years, provided the muscle for the latter.

In all, 71 people participated, with experts in birds, bats (and other beasts), reptiles and frogs, fish, insects, collembola, aquatic fauna and flora, soil invertebrates, snowbank invertebrates, spiders, velvet worms, vascular plants, horticultural plants, fungi, mycorrhizal fungi, lichens, mosses, liverworts and snow algae. The public was invited to participate and volunteers were on hand to help with sampling and also to enjoy the 'show and tell' held in the Thredbo Community Hall at the completion of the 24 hours.

Timing was always going to be a problem; there is, for example, a predictable sequence of insect emergence in the mountains and many adults are gone long before others emerge. We were never going to be in the right place at the right time for everything – the annual grasshoppers *Kosciuscola* had only reached their first instar whereas the Mountain spotted Grasshoppers *Monistria concinna* were well represented by all instars. Many of the herbs were in flower but we were about three weeks too early for the grasses.

Following the early spring thaw in the mountains, the following cool stretch – right up to snowfalls on Boxing Day – meant that snowbanks were still large and, with the sun shining on them, snow algae were blooming and warm conditions and strong winds just before the blitz dumped many insects on the snow surface ready to be collected. Warm nights also aided the entomologists with their insect traps.

Some species were easy to tick off (Crimson Rosellas and Snow Gums were never going to be a problem!). Ticking off the Platypus was a simpler job than expected with a visit to the pool just below the



Biologists sorting the catch from Lake Cootapatamba.

Brian Timms leads out with the Victorian punt above Lake Cootapatamba.

Thredbo Community Centre which resulted in a sighting within two minutes. To complete the monotremes, an Echidna wandered across the village green through groups of holiday makers. Even when surrounded by people it didn't go into its defensive dig-in mode but carried on its way. Among the rarer species, Mountain Pygmy-possums and a Broad-toothed Rat were caught on the summit of Mt Kosciuszko. Just down from the summit in the cross-drains beneath the walking track, the Mountain Galaxias *Galaxias olidus* showed which was Australia's highest fish. One intrepid researcher was given the task of documenting the feral fish using a dry fly (Brown Trout were confirmed).

Bats presented a problem. It was easy enough to set harp traps in flightways through the trees but above the treeline anabat detectors had to be used. The Lesser Long-eared Bat, Chocolate Wattled Bat and Southern Forest Bat were all caught and the White-striped Freetail Bat and Gould's Wattled Bat were identified from their calls.

Dead male alpine funnel webs were brought in by the public, their bodies are a common sight in January (nearly as commonly seen as the males at night in December as they wander across the grassland in search of females). It took a little more effort to find live funnel webs, but a live female was keen to demonstrate the difference between modern and primitive spiders. Primitive spiders have a vertical bite and have to strike like snakes whereas modern spiders bite horizontally.

Ted Edwards, who spent ten or so days in the area, collected an estimated 400 moth species including one last caught in 1922. Another moth was previously collected only once from Kosciuszko, the remaining specimens known only from Tasmania and Mt Buffalo. One new species was found, and another moth of interest was a larva of a Bogong Moth which turned up in a soil sample. Other insects of interest were parasitic flies found remote from their hosts.

Among rarities, with a little adjustment of the boundaries, we were able to include one of the last ten known ponds in NSW containing the endangered Alpine Treefrog *Litoria verreuxii alpina*, but it has been a long time since a Corroborree Frog has been seen anywhere near the search area. Thanks to the work of Alec Costin *et al.* (their *Kosciuszko Alpine Flora* was reviewed in volume 118 of *The Victorian Naturalist*), there were no surprises among the native vascular plants but we await the identification of mosses, lichens and liverworts where there may be some new species.

A report on the event with species lists will be published in time for the International Year of the Mountains Conference in November this year. Published by the Cooperative Research Centre for Sustainable Tourism (Griffith University) and the Australian Institute of Alpine Studies, it will contain the methods and the locations and where possible, a complete species list as well as any interesting findings to come out of the blitz.

Despite the complexity of the organisation it was good once again to participate in an effort to document simply what is out there as I creep towards my 25th anniversary of naturalising in the mountains.

Ken Green
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Editors' Note: To help celebrate the United Nations International Year of Mountains, Ken Green will be our 'Naturalist in the Mountains' during 2002. We look forward to publishing Ken's contributions about our mountain environments throughout the year.

Australian Natural History Medallion 2001

Alan Bridson Cribb

The winner of the 2001 Australian Natural History Medallion was Dr Alan Cribb, nominated by The Queensland Naturalists' Club for an outstanding contribution to natural history over a period of fifty years, culminating in his publication of the field guide *Seaweeds of Queensland*. The nomination was supported by The Royal Geographical Society of Queensland for Dr Cribb's contribution to four major expeditions, being involved in research project selection, overseeing the quality of submitted reports and refereeing submitted papers. He attended the expeditions to Cape York in the Wet Season and to the Lawn Hill National Park.

Alan Bridson Cribb graduated with a BSc from the University of Queensland in 1948 and subsequently gained a Masters degree and PhD from the same university. From the year of his graduation until 1988 he held positions at the University of Queensland except for a short time with CSIR Fisheries early in his career. He was in turn, demonstrator, lecturer, senior lecturer and finally Head of the Botany Department.

Dr Cribb is an authority in marine and freshwater algae concentrating on systematics of the Queensland flora, marine and terrestrial vegetation of the southern part of the Great Barrier Reef, and marine fungi. Voucher specimens from his research form the bulk of the reference collection at the Queensland Herbarium. In association with his responsibilities for teaching the principles of botany and biology of terrestrial plants, Alan Cribb has contributed significantly to the documentation of the distribution of Queensland flora by the provision of numerous checklists of plants for the National Parks and Wildlife Service. Many of these record new species or extensions of range. His work on the Great Barrier Reef led to a scheme of classification for the intertidal reef and several papers on the algal ecology of the area.

Dr Cribb has recorded his considerable research activities in a total of 149 papers and articles, 134 as sole author, and published six books, four jointly with his wife, Joan. His two books are *Marine Algae of the Southern Great Barrier Reef Part I. Rhodophyta* and the *Seaweeds of Queensland*. He has described a number of new species (24 algae, 14 marine fungi, one flowering plant). Alan and his wife kindled the current interest in native food which had hitherto been overlooked by the scientific community and general public.

In 1997 the Queensland Natural History Award was presented to Dr Cribb for his many contributions toward awareness and knowledge of natural history in Queensland. In addition to his academic achievements he introduced a course at the University of Queensland especially to provide an appreciation of botany for non-scientists. This theme was always present in his talks to natural history groups and to the public through radio and newspaper articles. He has led many field excursions for the Queensland Naturalists' Club and other groups and is a much appreciated exhibitor at Club meetings. In retirement since 1988, he has continued to promote public awareness of the contribution of plants to human welfare and their importance and role in biodiversity.

Dr Cribb has held membership of a number of professional and natural history societies within the State, nationally and internationally. This included the positions of Editor and President for the Queensland Naturalists' Club and twenty years on the council of the Great Barrier Reef Committee. He was elected Fellow of the Phycological Society (India).

In the area of conservation, Alan Cribb has put his expertise to good use by preparing submissions to relevant authorities. These have included reports and evidence to the Royal Commission on Petroleum Drilling on the Great Barrier Reef, the zoning of the Capricornia sec-

tion of the Great Barrier Reef Marine Park, and the revegetation of North Stradbroke Island after sand mining.

There are many people, not only members of the QNC but also the public in general, who are indebted to Dr Alan Cribb for new knowledge and understanding of natural history. For his contributions to botany, marine biology and conservation, he is a worthy recipient of the 2001 Australian Natural History Medallion.

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Graham Martin Pizzey

4 July 1930 – 12 November 2001

A note of sadness was struck at the presentation of the Australian Natural History Medallion on 12 November 2001, when Tom May, after welcoming some previous Medallionists, announced that Graham Pizzey had died that day. Graham Pizzey was awarded the Australian Natural History Medallion in 1986, in recognition of his long involvement with natural history and conservation, and his work in sharing this knowledge, through words and photographs, with the general public. He contributed a regular natural history column to *The Age* from 1954 to 1965 and to *The Herald* from 1965 to 1983. The importance of ecology and the need for conservation were reflected in the address he gave to the Club on receiving the Medallion. Too many people were unaware of the natural world, being focussed on material things, and the gap between them and those that appreciated it was wide, and he emphasised the need to develop a 'land ethic' whereby people saw themselves as belonging to the land rather than its being something to be exploited.

Graham Pizzey played a significant part in the campaign to protect the Little Desert in the late 1960s, and in the conservation movement which culminated in the establishment of the Land Conservation Council in 1971, which led to a great increase in protected land across the State. He was a member of the National Parks Authority from 1967-1971. In 1981 he was appointed warden of the wildlife sanctuary at Coolart, on Westernport Bay, greatly appreciating the opportunity of involving the public in the development of this important wetlands site. Following this, in 1984, he and his wife, Sue, began a search which led ultimately to their acquiring a piece of natural bushland near Dunkeld, in the Grampians, where, as he described in articles in *The Age*, they could live and observe nature, and provide an opportunity for paying guests to share in this experience.

Although the move to Dunkeld meant that Graham no longer participated in many of the organisations with which he had been involved, he continued as honorary ornithologist to the Museum of Victoria, and up until the time of his death he was working on the protection of the Brolga in western Victoria.

Birds were Graham Pizzey's major interest and his authoritative book, *A Field Guide to the Birds of Australia*, meticulously researched and illustrated over 15 years, was published in 1980. It ran to 14 editions; the latest, completely revised, appeared in 1997 and became a bestseller.

Graham Pizzey was a member of the Field Naturalists Club of Victoria from 1962 to1994.

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Wyperfeld: Australia's First Mallee National Park

by Geoff Durham

Publisher: *Friends of Wyperfeld National Park Inc., Elsternwick, Victoria, 2001. Paperback, viii + 200 pp (including maps, black & white, and colour photographs, and eleven appendices). ISBN 0 646 40101 7. RRP $25.00.*

On the cover of this book is a picture of the setting sun silhouetting a kangaroo and her joey. Red light catches the hair around her body and the grass at her feet, broken up only by the long shadows cast by tree trunks behind her. It is a scene recalled with pleasure by campers in any of the Mallee national parks of northern Victoria. The solitude, and remoteness, the ancient landscape, the regular sightings of large fauna, the colourful sunsets followed by brilliant starry skies on clear nights are all attractions to travel to these wonderful places.

Wyperfeld National Park was, as the title of the book says, Australia's first Mallee national park. It started life as a 9,600 acre (3,885 ha) reservation in 1909 and has been added to a dozen times subsequently, with the latest addition in 1992, making it, at 357,097 ha, the third largest national park in Victoria (behind the Alpine and Murray-Sunset National Parks). Wyperfeld lies in the north-western part of Victoria in an area known as the Mallee and is dominated by Mallee vegetation. The original section of the Park was in the parish of Wyperfeld but the origin of that name is obscure.

My father, Ian Maroske, was a member of the Committee of Management of Wyperfeld National Park (later Advisory Committee) from 1959 to 1993 when he retired as Chairman. He joined after curiosity about the large blanks on maps of north-western Victoria led him to explore the area. In his more than thirty years of service he visited the Park numerous times and his delight in what he saw never dimmed, nor his wish to share that pleasure with others. His papers on the Park are now held at the State Library of Victoria, and include information for a book that he was never able to publish.

If he had lived to see the use that Geoff Durham has made of these and other materials he would have been very gratified. *Wyperfeld: Australia's First Mallee National Park* is as handsome, accessible, concise and informative a manual as anyone could wish to see, and one that no visitor to the Park will wish to be without. Durham has presented an absorbing story of the Park in 15 chapters accompanied by numerous photos, maps and diagrams, all carefully laid out by Leon Costermans. There are eleven appendices at the end of the book (including lists of plants and animals and an explanation of place names), a bibliography and a comprehensive index.

The first part of the book deals with the history of the Park. It includes information on diverse topics such as the land, its people and wild life, which Durham weaves together skilfully into a sustained narrative. The Wotjobaluk were dispossessed of their land when the first settlers arrived in the area in 1848. Within 50 years Wotjobaluk culture was shattered and the land also changed irrevocably. The birds, however (including the Mallee Fowl), were still sufficiently abundant at the end of the century to attract the notice of field naturalists and these visitors were the driving force in getting the first piece of land reserved as a park in 1909.

Durham's chapters on natural history are particularly good. In chapter four he describes the three seasons of the Park, dry, cold and breeding, and the ways in which organisms have adapted to live through them. Settlement has more often than not disrupted these relationships. Exotic pests, large bush fires, reduced water flows and so on have all created management problems. For example, Cypress Pines burnt out around Lake Brimin in 1946 showed no signs of regenerating naturally due to overgrazing by rabbits as well as kangaroos. They have been replanted by hand and netted to protect them, the nets only recently having been removed.

In part two of the book, four distinctive regions of the Park are described in detail: the flood plain, Pine Plains, the eastern interface and the western wilderness. The flood plain is the termination of the Wimmera River and splits the Park in two from south to north. Floods are now rare in the Park and one of my cherished memories is of swimming in Outlet Creek in 1976 (the last time that water reached the Park). The northern most point of the flood plain is Wirrengren Plain which is part of Pine Plains. The land to the east of the flood plain is a strong-hold of the Mallee Fowl and to the west is a wilderness which almost doubled the size of the Park when it was incorporated in 1991.

Part three of the book consists of general visitor information. It details facilities at Wonga Camp Ground and Casuarina Camp Ground in the Park, and in nearby settlements. The established walks and drives in the Park are sufficiently numerous and various to suit most kinds of visitors. Maps and some notes (especially for the drives) are provided in the book and complement the information sheets produced by Parks Victoria. Additional information on the Park can be found using the bibliography at the back of the book, or making a trip to the Information Centre at Wonga Camp Ground.

I have many wonderful memories of Wyperfeld National Park. As a child I recall the approach through seemingly interminable cleared land to the south. At last the rustic gateway (no longer extant) would appear in front of the car and we would pass through into the bush with evidence of European settlement rapidly receding. We followed a ribbon of Black Box along the course of Outlet Creek to Wonga Camp Ground on the lookout for kangaroos and emus. There we were often met by the Park's first Ranger Rudd Campbell who always had some peppermints for my brother and sister and me.

Wyperfeld is not a place of dramatic vistas like Mt Buffalo or Wilsons Promontory, but its landscape is attractive. This wonderful book will make an important contribution to increasing appreciation of the Park. It is, as it says of itself, 'an invitation, an introduction and a practical guide with background information to enhance every visit'. It was published by the Friends of Wyperfeld National Park and will make the Park many new friends. I will have it, open, in my hand on my next visit to the Park, which I hope will be very soon.

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Footnote: The book's editor, Leon Costermans, wishes to record some corrections to minor errors which occurred in the production process.

Page 43: The caption for photo 6 should read '6 **Copper Stag** beetle (*Lamprima varians*)'.

Where *Stipa* is given in the text as the genus for Spear-grass species, this is synonymous with the more recent *Austrostipa* S.W.L. Jacobs and J. Everett (1996), as given in the plant list on page 152.

Page 111: The photo caption should read 'An overnight bushwalking group at **Wonga** Lake'. (Round Lake is not ringed by Red-gums!).

Page 136: Under **Walks**, delete the word 'Track' in '... south-west to Outlet Creek Track ...'.

Page 139: In the paragraph under **Day visitors**, replace the last sentence with 'From here, the gravel road is usually reasonable for two-wheel drive vehicles for 10 km northwards'.

Page 156: Under Epacridaceae, the common name for *Brachyloma ericoides* subsp. *ericoides* should read **Brush Heath**. ('Pink Beard-heath' is *Leucopogon ericoides* which is not recorded north of the Little Desert).

Page 171: After Silver Gull (*Larus novaehollandiae*), delete the code 'A'.

Page 190: In the **Bibliography**, add: Cogger, H.G. 2000, *Reptiles & Amphibians of Australia*, 6th edn, Reed New Holland, Sydney. This is referred to on page 168.

In the index, several page references are in error by one page, due to last-minute layout adjustments.

July 2001

Guidelines for Authors – The Victorian Naturalist

Submission of all Manuscripts

Authors may submit material in the form of research reports, contributions, naturalist notes, letters to the editor and book reviews. A ***Research Report*** is a succinct and original scientific paper written in the traditional format including abstract, introduction, methods, results and discussion. A ***Contribution*** may consist of reports, comments, observations, survey results, bibliographies or other material relating to natural history. The scope of a contribution is broad and little defined to encourage material on a wide range of topics and in a range of styles. This allows inclusion of material that makes a contribution to our knowledge of natural history but for which the traditional format of scientific papers is not appropriate. Research reports and contributions must be accompanied by an abstract of not more than 200 words. The ***abstract*** should state the scope of the work, give the principle findings and be complete enough for use by abstracting services. Research reports and contributions will be refereed by external referees. ***Naturalist Notes*** are generally short, personal accounts of observations made in the field by anyone with an interest in natural history. These may also include reports on excursions and talks, where appropriate, or comment on matters relating to natural history. ***Letters to the Editor*** must be no longer than 500 words. ***Book Reviews*** are usually commissioned, but the editors also welcome enquiries from potential reviewers.

Submission of a manuscript will be taken to mean that the material has not been published, nor is being considered for publication, elsewhere, and that all authors agree to its submission.

Three copies of the manuscript should be provided, each including all tables and copies of figures. Original artwork and photos can be withheld by the author until acceptance of the manuscript. Manuscripts should be typed, double spaced with wide margins and pages numbered. Please indicate the telephone number (and email address if available) of the author who is to receive correspondence.

Electronic versions of the manuscript are only required upon resubmission after referees' comments have been incorporated. Documents should be in Microsoft Word for Windows v2 to ensure compatibility with the typesetting software Quark Xpress. Other PC formats may be accepted (e.g. RTF or later versions of MS Word), but additional type-setting time is required with the subsequent delay of publication.

Taxonomic Names

Cite references used for taxonomic names. References used by *The Victorian Naturalist* are listed at the end of these guidelines.

Abbreviations

The following abbreviations should be used in the manuscript (with italics where indicated): *et al.*; pers. obs.; unpubl. data; and pers. comm. which are cited in the text as (RG Brown 1994 pers. comm. 3 May). Use 'subsp.' for subspecies.

Units

The International System of Units (SI units) should be used for exact measurement of physical quantities.

Figures and Tables

All illustrations (including photographs) are considered as figures and will be designed to fit within a page (115 mm) or a column (55 mm) width. **It is important that the legend is clearly visible at these sizes.** For preference, photographs should be of high quality/high contrast which will reproduce clearly in black-and-white. They may be colour slides, colour or black-and-white prints. Line drawings, maps and graphs may be computer generated or in black Indian Ink on stout white or tracing paper. The figure number and the paper's title should be written on the back of each figure in pencil. Computer-generated figures should be submitted as high-quality TIFF or encapsulated postscript (EPS) files of at least 600 dpi, either separately on disc or embedded into a MS Word document. Low-resolution JPG files will not be accepted.

Tables must fit into 55 mm or 115 mm. If using a table editor, such as that in MS Word, do not use carriage returns within cells. Use tabs and not spaces when setting up columns without a table editor.

All figures and tables should be referred to in the text and numbered consecutively. Their captions must be numbered consecutively (Fig. 1, Fig. 2, etc.) and put on a separate page at the end of the manuscript. Tables should be numbered consecutively (Table 1, Table 2, etc.) and have an explanatory caption at the top.

Please consult the editors if additional details are required regarding document formats and image specifications. Authors who are not computer literate should contact the editors to make special arrangements.

Journal Style

Authors are advised to note the layout of headings, tables and illustrations as given in recent issues of the Journal. **Single spaces** are used after full stops, and **single quotation marks** are used throughout.

In all papers, at the first reference of a species, please use both the common name and binomial. However, where many species are mentioned, a list (an appendix at the end), with both common and binomial names, may be preferred. Lists must be in taxonomic order using the order in

which taxa appear in the references recommended below.

The journal uses capitalised common names for species followed by the binomial in italics without brackets, e.g. Kangaroo Grass *Themeda triandra*.

References

References **in the text** should cite author and year, e.g. Brown (1990), (Brown 1990), (Brown 1990, 1991), (Brown 1995 unpubl.), (Brown and Green 1990), (Brown and Green 1990; Blue 1990; Red 1990). If there are more than two authors for a paper use Brown *et al.* (1990). These should be included under **References**, in alphabetical order, at the end of the text (see below). The use of unpublished data is only accepted if the data is available on request for viewing. Pers. obs. and pers. comm. should not be included in the list of references. **Journal titles should be quoted in full.**

Leigh J, Boden R and Briggs J (1984) *Extinct and Endangered Plants of Australia*. (Macmillan: South Melbourne)

Lunney D (1995) Bush Rat. In *The Mammals of Australia*, pp 651-653. Ed R Strahan. (Australian Museum/Reed New Holland: Sydney)

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Wolf L and Chippendale GM (1981) The natural distribution of *Eucalyptus* in Australia. Australian National Parks and Wildlife Service, Special Publications No 6, Canberra.

Other methods of referencing may be acceptable in manuscripts other than research reports, and the editors should be consulted. For those using the bibliographic software 'EndNote', a style guide for *The Victorian Naturalist* will be available shortly on our website. For further information on style, write to the editors, or consult the latest issue of *The Victorian Naturalist* or *Style Manual for Authors, Editors and Printers* (Australian Government Publishing Service: Canberra).

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Checking species names is the responsibility of authors. The books we would like used as references for articles in *The Victorian Naturalist* are listed below. **Authors should refer to the source used for species names in their manuscripts.** In every case, the latest edition of the book should be used.

Mammals – Menkhorst PW (ed) (1995) *Mammals of Victoria: Distribution, Ecology and Conservation*. (Oxford University Press: South Melbourne)

Reptiles and Amphibians – Cogger H (2000) *Reptiles and Amphibians of Australia*, 6 ed. (Reed Books: Chatswood, NSW)

Insects – CSIRO (1991) *The Insects of Australia: a textbook for students and research workers*. Vol I and II. (MUP: Melbourne)

Birds – Christidis L and Boles W (1994) *The Taxonomy and Species of Birds of Australia and its Territories*. Royal Australian Ornithologists Union Monograph 2. (RAOU: Melbourne)

Plants – Ross JH (ed) (2000) *A Census of the Vascular Plants of Victoria*, 6 ed. (Royal Botanic Gardens of Victoria: Melbourne)

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How to Identify Wildflowers of the Grampians

by Ken Woodcock

Publisher: *The Community Association of Halls Gap Inc. RRP $10.50*

This is an unusual little book illustrated with 150 very small colour drawings and minimal text. There are six illustrations on each page and species are grouped according to flower colour. This presents some problems in grouping the blue, violet, mauve and pink species, where the subtle colour differences are notoriously difficult to describe or reproduce. The descriptions are brief with one or two important features arrowed on the drawing. Both the common and botanical names are given but any technical or botanical terms are entirely avoided. This makes it easy for beginners in wildflower study and should enable recognition at least to genus. However problems may occur in differentiating the species in genera such as *Hibbertia* or in the pea flowers, where subtle differences in leaf characters can be critical. For example no mention is made of the leaves being in very obvious opposing pairs (decussate) in *Eutaxia.* This character is easy to see and distinguishes *Eutaxia* from all other yellow or orange flowered peas in the Grampians. A note or sketch of the legume shape would also have been helpful in sorting out the peas.

Keeping abreast of changing nomenclature is a problem for both authors and naturalists. This should not deter beginners from learning about native plants; even the most knowledgeable of naturalists are rarely completely up to date. An addendum paragraph after the index lists some recent changes; however *Leionema bilobum* is still the valid name for what was formerly *Phebalium bilobum.* The illustration of *Utricularia* is presumably *U. dichotoma,* not *U. uniflora* that is an East Gippsland species.

This very elementary and relatively cheap little book could be useful to those totally unfamiliar with wildflowers and would probably enable them to recognise many of the common flowers, at least to genus. Anyone seeking more information would need to refer to one of the several other more detailed and comprehensive books dealing with Grampians plants.

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Birds of Box Hill

by Tess Kloot with illustrations by Nicolas Day

Publisher: *Victorian Ornithological Research Group, 2000. RRP $18.00 (+ $2 postage per copy) (Order from VORG, 133 Graydons Road, Moorooduc, Victoria 3933)*

The Birds of Box Hill derives from a study undertaken by the Victorian Ornithological Research Group (VORG) between 1988 and 1991, and it is refreshing to see amateur research organizations publishing the fruit of their work in a manner accessible to the public. This book certainly has a lot in it that will appeal, especially to the residents of Box Hill and other eastern suburbs of Melbourne. The VORG survey arose from a desire to compare the avifauna of Box Hill in the late 1980s with that recorded by one Robert Hall, a local naturalist, in the 1890s, when Box Hill was a sparsely populated area. The book not only presents a guide to the birds found in the Box Hill area but also presents the reader with an idea of the abundance of each species and will be useful for generations to come as a base-line of the avifauna of an established suburb. When Robert Hall was conducting his original surveys the area was mainly a collection of farms with much remnant vegetation - times have certainly changed.

The first part of the book is basically a field guide to the birds of Box Hill, with concise, pertinent text and excellent black and white illustrations from Nicolas Day. However the use of colour would have been far more desirable in an identification guide aimed at novices. In all a respectable 78 species were recorded on a regular basis and are illustrated, with eight being introduced. The thirty-seven species that were infrequently recorded during the VORG survey (seen four times or less) include some very interesting and exciting sightings such as Swift Parrot, Baillon's Crake, Rufous Songlark and some obvious escapees such as Budgerigar and Zebra Finch. These species are not illustrated which I think is entirely appropriate if the field guide portion of this book is aimed at novices.

The chapter on Selected Birdwatching Areas of Box Hill gives a good guide to these areas although this chapter and those on Parks and Gardens of Box Hill and Birds Recorded in Selected Areas could have been combined. I really enjoyed reading the chapters on the history of Box Hill and on Robert Hall's work. Lots of interesting snippets and facts can be gleaned from this book. I particularly liked the list of birds recorded at the end of the 19th century which includes their common name of the time, for example Sordid Woodswallow (Dusky Woodswallow), Funeral Cockatoo (Yellow-tailed Black Cockatoo), and Rose Hill Parrot (Eastern Rosella).

I have one major quibble with the book given that there are chapters on Attracting Birds to your Garden, Robert Hall (1867-1949) One Hundred Years On, and The History of Box Hill (which includes the origin of the suburb's name) there is very little prominence given to the vegetation of the area and its change over the past century. I am none the wiser after reading this book about the original flora of this area. Although given the loss of woodland bird species (White-winged Chough, Diamond Firetail, Regent Honeyeater, Spotted Quail-thrush, Brown Treecreeper and Speckled Warbler for example) in the past hundred years it is presumed that a large part of the area was open eucalypt (box) woodland with a grassy understorey.

All up a terrific little book that will hopefully appeal to residents of Melbourne's middle eastern suburbs and those of us who have a deeper interest in the changes in Victorian avifauna wrought over the last hundred years. If it inspires only some Box Hill residents to take more interest in their natural surrounding, which it will, it should be considered a great success.

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The

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Index to Volume 118, 2001 is in the centre of this issue

Research Reports A Herpetofauna Survey of the Victorian Alpine Region, with a Review of Threats to These Species, *by Nick Clemann*.....48

The Mammals of Parker River Inlet, Otway National Park, *by ME Westbrooke and PT Prevett*.....60

Contribution Habitat of the Endangered *Hibbertia procumbens* (Labill.) DC (Dilleniaceae) from the Central Coast of New South Wales, *by Stephen AJ Bell*.....69

Naturalist Notes Wingan Wilderness, *by Ron Fletcher*.....74

Naturalist in the Mountains The Changing Mountains, *by Ken Green*.....76

Tributes Jack Hyett OAM, *by Cecily Falkingham*.....78

Alexander Clifford Beauglehole, *by Margaret Corrick*.....81

Book Reviews Birds of Box Hill, *by Tess Kloot with illustrations by Nicolas Day, reviewed by Stuart Dashper*.....46

Wild Solutions: How Biodiversity is Money in the Bank, *by Andrew Beattie and Paul Ehrlich, reviewed by TR New*.....58

A Field Companion to Australian Fungi, *by Bruce Fuhrer, reviewed by Jenny Tonkin*.....79

Wildflowers of Sydney and Adjoining Areas, *by Alan Fairley, reviewed by Cecily Falkingham*.....83

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Cover: Tall Everlasting *Helichrysum elatum* photographed by Ron Fletcher at Wingan Inlet. See Naturalist Note on page 74.

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A Herpetofauna Survey of the Victorian Alpine Region, with a Review of Threats to These Species

Nick Clemann[1]

Abstract
A wide-ranging survey of the reptiles and frogs of the Victorian alpine region was conducted in summer and early autumn 2001. Eight habitat 'types' that were easily discernible in the field were identified, and randomly-positioned sites chosen in these habitats. Surveys of these sites were conducted using 'active search' techniques, and results bolstered with incidental records. Three frog and eleven reptile taxa were recorded across all areas and habitat types. Notable records included a range extension for the threatened Alpine Bog Skink *Pseudemoia cryodroma*, and the collection of specimens of undescribed lizards from the genus *Egernia* from the Bogong High Plains, Davies Plain and Mt Bogong. Threats to Victorian alpine herpetofauna are discussed, as is the dramatic decline in many areas of the Alpine Tree Frog *Litoria verreauxii alpina*. (*The Victorian Naturalist* **119** (2), 2002, 48-58)

Introduction

The herpetofauna (reptiles and frogs) of the alpine region of Victoria is largely endemic to alpine areas, the general ecology of these taxa is poorly understood, and they face a suite of threatening processes. The aim of this project was to refine our understanding of the habitat associations of these taxa, and the processes that threaten them. To this end, a broad-scale field survey and a detailed literature search were carried out.

The alpine region of Victoria embraces the highest plateaux in the State, and extends from the Mt Cobberas area near the border with New South Wales in the north-east, along the top of the Great Dividing Range, to the Mt Baw Baw area in the south-west. This region can be crudely defined as commencing at about 1200 m altitude, and extending to the highest point in Victoria, the summit of Mt Bogong at 1986 m. It receives a consistent snow cover during winter months.

The alpine region contains several species of threatened herpetofauna. This fauna (with threatened categories according to NRE (2000) in parentheses) includes: Alpine Tree Frog *Litoria verreauxii alpina* (listed as Vulnerable nationally on Australian and New Zealand Environment and Conservation Council (ANZECC 1999) and *Endangered Species Protection Act* 1992 lists, and Critically Endangered in Victoria), the Baw Baw Frog *Philoria frosti* (Vulnerable on the ANZECC list, Critically Endangered in Victoria), Alpine Water Skink *Eulamprus kosciuskoi* (Critically Endangered), Alpine She-oak Skink *Cyclodomorphus praealtus* (Endangered), Alpine Bog Skink *Pseudemoia cryodroma* (Vulnerable, and endemic to Victoria) and Glossy Grass Skink *Pseudemoia rawlinsoni* (Lower Risk – Near Threatened). With the exception of the Glossy Grass Skink, these species are restricted to alpine areas. In addition to these species, two undescribed taxa of the scincid genus *Egernia* occur in the region. Draft Action Statements have been developed for the Alpine Water Skink (Meredith *et al.* in press) and Alpine She-oak Skink (Clemann in press).

The biology and ecology of these species are poorly known, as are the processes that threaten them. Plausibly, these threats include grazing and trampling of habitat by cattle, feral horses and deer, predation by introduced carnivores such as cats and foxes, habitat modification or destruction due to development (e.g. ski resort infrastructure, walking and vehicular tracks), recreational activities or the invasion of weeds, illegal collection, inappropriate fire regimes and global warming due to the effect of greenhouse gases. This latter process is of particular concern for alpine fauna; under an enhanced greenhouse scenario, considerable contraction of alpine habitat may occur, with little or no opportunities for emigration to other suitable locations. Whilst the Alpine Tree Frog is known to have suffered major declines throughout much of its range (Gillespie *et al.* 1995; Hunter *et al.* 1997), the current status of alpine reptiles is poorly known. However, some of these species may also

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have declined due to one or more of these processes.

The alpine region of south-eastern Australia contains other threatened alpine vertebrate species: Southern Corroboree Frog *Pseudophryne corroboree* (Endangered in NSW), Northern Corroboree Frog *P. pengilleyi* (Vulnerable in New South Wales), and the Mountain Pygmy Possum *Burramys parvus* (Vulnerable on the ANZECC list, Endangered in Victoria). Several vegetation communities, namely the Alpine Bog Community, Alpine Snowpatch Community and Fen (Bog pool) Community, are also listed on Schedule 2 of the Victorian *Flora and Fauna Guarantee Act* 1988 (FFG). Also listed on the FFG as a potentially threatening process is soil erosion and vegetation damage and disturbance caused by cattle grazing.

Methods

Study areas

Study areas were selected to represent alpine areas across north-eastern Victoria that were relatively accessible and have a continuing history of human presence, and thus were likely to contain a considerable degree of anthropogenically-generated disturbance. Examples of the processes that typify such disturbances include mining, recreational pressure, resort development, stock and feral herbivore grazing and trampling, and track and road construction. Logistic and time constraints restricted surveys to plateaux with relatively easy access. As such the following areas were chosen for surveys: Mt Buller/Mt Stirling, the Dargo High Plains, Davies Plain, Dinner Plains, Falls Creek/Bogong High Plains, the Howitt Plains, Lake Mountain, Mt Bogong and Mt Buffalo. Several of these 'areas' are generic terms for series of alpine plains. For example 'Howitt Plains' incorporates areas such as Bryces, Snowy and Bennison Plains; 'Dinner Plains' incorporates areas such as Flourbag, Horsehair and Emu Plains; and 'Dargo Plains' incorporates areas such as Gow, Lankey, Treasure, Halfway and One Pole Plains.

Habitat

Eight broad habitat types that were easily identified in the field (bog, cleared and/or disturbed, tussock grassland, rocky grassland, heathland, montane dry woodland, Snow Gum *Eucalyptus pauciflora* woodland and Rocky Outcrop Shrubland/Herbland Mosaic – this last habitat type is specific to the Mt Buffalo area) were chosen for general herpetofauna surveys, and an effort made (where possible) to sample two sites in each habitat type in each area. Although most of these sites showed varying degrees of disturbance, sites classified as 'cleared/disturbed' were usually grossly modified. These sites included areas such as cattle yards, ski runs, and areas used for rock or gravel extraction or surrounding human developments such as huts and carparks.

These eight habitat types often were not strictly discrete, and considerable variation and overlap between habitat types was evident. For example, 'heathland' sites were often found to surround bogs. This meant that, whilst surveying a 'bog' site, this site would grade into heath (and vice versa), often with dense *Epacris* sp. in the intergrade zone. 'Grasslands' were often a combination of tussock grass, herbfields and very low (usually < 30 cm high) heath. Snow Gum woodland, whilst always dominated by an overstorey of Snow Gum, varied markedly in understorey and groundstorey composition. For example, some Snow Gum woodland sites contained extremely dense, head-high heath, others contained a low, tussock grass groundcover, and many were intermediate between these extremes. Similarly, some Snow Gum sites contained numerous, large rock outcrops, whilst others were devoid of rocks.

Site selection

Within each survey area ('Study areas' above) a series of random grid points was generated and plotted onto maps. Once in the field, these grid points were considered potential sites, and were visited (with emphasis on those sites within a reasonable walking distance from roads and tracks) and systematically surveyed until two sites had been sampled in each habitat type in each area. All other grid points were then disregarded. Using this systematic approach, grid points that occurred in habitats that had already been adequately surveyed were also disregarded. Wherever possible, all sites were located more than

one km from any other site. Not all habitat types were detected in each area. In some areas it was only possible to locate enough habitat to survey one site in some habitat types. Also, in some areas it was necessary to select habitat in a non-random manner, because there were only one or two patches of this localised habitat in some general survey areas.

Survey techniques

Within each site a time-constrained (20 minute) 'active search' limited to the appropriate habitat type was conducted between the hours of approximately 0800-1830 daylight savings time. This technique involved noting all basking or active reptiles, and any frog calling activity. Rocks and logs were rolled, soft logs were cleaved, loose bark was peeled, and litter and gravel sifted to detect sheltering animals. At each site the habitat type and any obvious disturbance were noted, and general weather variables such as temperature, cloud cover and wind velocity were recorded.

This application of a single survey technique for a variety of taxa has obvious limitations, including failure to detect particularly cryptic species, and a high likelihood of underestimating the abundance of species that are difficult to detect during active searching. For example, species that prefer dense tussock grass habitat are usually very difficult to detect or capture (for confident identification) using this technique. Thus, the following results provide only a coarse index of abundance.

Results

Three frog taxa (Alpine Tree Frog, Common Froglet *Crinia signifera* and Victorian Smooth Froglet *Geocrinia victoriana*) and 12 reptile taxa were recorded either during surveys or incidentally (Table 1). Several threatened taxa were also recorded, and these included the Alpine Tree Frog on the Dargo Plains and Mt Bogong, Alpine Water Skink on Davies Plain and the Bogong High Plains north-east of Falls Creek, and Alpine Bog Skink in the Buller/Stirling, Davies Plain, Howitt Plains, possibly Mt Buffalo (see below) and Lake Mountain areas. This latter locality represents an extension of the known range of this species.

Several specimens of *Pseudemoia* could not be confidently assigned to a particular species. In particular, there was confusion regarding intermediate colouration and morphology between specimens of *P. cryodroma* and *P. pagenstecheri*. Voucher specimens of these taxa from these areas were sent to the South Australian Museum (whose staff described these taxa) for resolution. Despite this, some specimens from Mt Buffalo could not be confidently identified.

Specimens of undescribed lizards from the genus *Egernia* were collected on the Bogong High Plains (Ruined Castle south of Falls Creek), Davies Plain and Mt Bogong. Additionally, a gravid female had been collected on Mt Buffalo in December 1997, and one of this lizard's offspring has been sent to the South Australian Museum for taxonomic study, along with the *Egernia* and *Pseudemoia* specimens collected during the present study.

The Alpine She-oak Skink was not recorded during this study, despite surveys and incidental searches in localities from which this species had previously been recorded (Lankey Plain on the Dargo High Plains, Ruined Castle and Basalt Hill on the Bogong High Plains and several localities in the vicinity of Mt Hotham) (Schulz *et al.* 1995; Heinze 1997; Schulz and Mansergh 1997; Atlas of Victorian Wildlife database).

Two taxa were recorded from only a single area. The Victorian Smooth Froglet was detected in the Mt Buller/Mt Stirling area, and the Black Rock Skink *Egernia saxatilis intermedia* was detected on Mt Buffalo (Table 1). The Alpine Water Skink was detected only on Davies and the Bogong High Plains. Conversely, the Southern Water Skink *Eulamprus tympanum* was detected at eight of the nine areas, and Tussock Skinks *Pseudemoia pagenstecheri* were recorded at seven.

Davies Plain yielded the highest number of taxa (not including taxa not identified to species level) during this study, with 10 species, whilst nine were recorded on the Howitt Plains (Table 1). All of the other areas returned between five and eight species.

The mean number of reptile species recorded for each habitat type was four (4.4 when Rocky Outcrop Shrubland/

Table 1. Herpetofaunal species recorded during surveys of the Victorian alpine region, within each broad locality. Status – taxa that are listed as threatened in Victoria, with their relevant status according to NRE (2000): Crit End, Critically Endangered; Vul, Vulnerable. FFG – Victorian *Flora and Fauna Guarantee Act* 1988: L denotes taxa listed under this legislation). A.S. – status of Action Statements for taxa that are listed on the FFG (once a taxon, community or threatening process is listed on the FFG, an Action Statement must be prepared in a 'reasonable amount of time'). Locality key: Bull/Stir, Buller/Stirling; Dargo Plains, Dargo Plains; Davies, Davies; Dinner Plain, Dinner Plain; Falls/Bog HP, Falls/Bogong HP; Howitt Plains, Howitt Plains; Lake Mtn, Lake Mountain; Mt Bog, Mt Bogong; Mt Buf, Mt Buffalo. ?, probable identification only; specimens unable to be confidently differentiated from *P. pagenstecheri*; S, recorded during a standardised survey (see Methods for an explanation of survey techniques); I, incidental records. *Offspring of female collected December 1997 during the North East Victorian Regional Forestry Agreement surveys.

Species	Common Name	Status	FFG	A.S.	Bull/ Stir	Dargo Plains	Davies	Dinner Plain	Falls/ Bog HP	Howitt Plains	Lake Mtn	Mt Bog	Mt Buf
Frogs													
Litoria verreauxii alpina	Alpine Tree Frog	Crit End	L	No	-	SI	-	-	-	-	-	I	-
Crinia signifera	Common Froglet	-	-	-	-	-	S	S	SI	SI	S	-	S
Geocrinia victoriana	Victorian Smooth Froglet	-	-	-	I	-	-	-	-	-	-	-	-
Reptiles													
Austrelaps ramsayi	Highland Copperhead	-	-	-	I	I	-	S	I	S	-	-	-
Drysdalia coronoides	White-lipped Snake	-	-	-	S	-	S	-	I	-	-	S	-
Bassiana duperreyi	Eastern Three-lined Skink	-	-	-	-	-	S	-	-	S	-	-	-
Egernia sp.	Undescribed *Egernia*	-	-	-	-	-	I	-	S	-	-	I	I*
Egernia saxatilis intermedia	Black Rock Skink	-	-	-	-	-	-	-	-	-	-	-	SI
Eulamprus kosciuskoi	Alpine Water Skink	Crit End	L	Draft	-	-	SI	-	SI	-	-	-	-
Eulamprus tympanum	Southern Water Skink	-	-	-	SI	SI	SI	SI	SI	SI	SI	-	I
Eulamprus sp.	Unidentified Water Skink	-	-	-	-	-	-	-	-	I	-	-	-
Niveoscincus coventryi	Coventry's Skink	-	-	-	-	-	I	-	-	S	-	-	-
Pseudemoia cryodroma	Alpine Bog Skink	Vul	L	No	SI	-	S	-	-	S	S	-	?
Pseudemoia entrecasteauxii	Southern Grass Skink	-	-	-	-	SI	SI	S	SI	-	SI	S	-
Pseudemoia pagenstecheri	Tussock Skink	-	-	-	SI	S	-	SI	SI	SI	-	SI	S
Pseudemoia spenceri	Spencer's Skink	-	-	-	S	-	I	SI	-	S	I	-	-
Pseudemoia sp.	Unidentified Grass Skink	-	-	-	-	S	S	-	-	-	S	-	-
Unidentified scincid		-	-	-	SI	S	S	SI	S	SI	S	S	S

Herbland Mosaic, found only on Mt Buffalo is disregarded). Both the Southern Grass Skink *Pseudemoia entrecasteauxii* and Tussock Skink were recorded in six habitat types, and the Southern Water Skink in five (Table 2). Species recorded in only one habitat type include Coventry's Skink *Niveoscincus coventryi*, Black Rock Skink and *Egernia* sp. (although these undescribed taxa were also incidentally recorded in Snow Gum woodland). The Alpine Water Skink was recorded in two habitat types (bog and heathland), although they show considerable overlap.

Bog habitat yielded the highest number of reptile species (six) across all areas, whilst heathland and rocky grassland returned five species (Table 2). Other habitat types yielded three or four species, with the exception of Rocky Outcrop Shrubland/Herbland Mosaic (one species from two sites on Mt Buffalo).

The largest reptile occurring in the alpine region, the Highland Copperhead *Austrelaps ramsayi*, was recorded at five of the eight study areas. This species occasionally reaches considerable densities for a top-order predator, with up to four adults recorded in areas of approximately 1600 m^2 during this study. These high densities were noted where there was also a high abundance of scincid lizards, particularly Southern Water Skinks.

Discussion

During this study the Alpine Tree Frog was not detected at several localities such as Lake Mountain and the Howitt, Davies and Bogong High Plains where it was once known to be abundant and where many specimens of this subspecies in the Museum Victoria collection originate (Atlas of Victorian Wildlife database). Most of these specimens were collected in the 1960s and '70s. The last records of this frog from Lake Mountain and Davies Plain were from 1993 and 1994, respectively (Atlas of Victorian Wildlife database). Whilst intensive frog surveys have been conducted during the breeding season of the Alpine Tree Frog on Mt Baw Baw (where this taxa was once abundant) for the last six years, no specimens have been detected, suggesting that this frog no longer occurs in this area.

The apparent declines detected in the present study accord with those detected by other authors. The population status of this taxon was reviewed in 1995 (Gillespie *et al.* 1995), at which time it appeared that it had suffered major population declines in the Australian Capital Territory and Kosciusko National Park in New South Wales. Subsequent surveys funded by the Alps Liaison Committee confirmed major declines in this region of its range, but did not adequately assess the taxon's status in Victoria. Other targeted frog surveys conducted on Mt Baw Baw (G Hollis unpubl. data) and Lake Mountain (B Malone pers. comm.) indicate that the taxon has disappeared from these parts of its former range. Osborne *et al.* (1999) suggest that the Alpine Tree Frog is in immediate danger of extinction in New South Wales and is highly threatened in Victoria.

Current knowledge of the status of the Alpine Tree Frog and the nature of declines has been reviewed recently (Osborne *et al.* 1999). It is clear that these declines have occurred concurrently with those in all other endemic alpine frog taxa (*Philoria frosti, Pseudophryne corroboree, P. pengilleyi, Limnodynastes dumerilii fryi*). However, it is still unclear what the causes of these declines are. Possible causes include changes in climate and increased ultraviolet radiation. The disease Chytridiomycosis, caused by a fungal pathogen, has recently been implicated in the decline of numerous frog species, including taxa closely related to the Alpine Tree Frog (Berger *et al.* 1999), and may yet be found to be contributing to the decline of the taxon. Post-European settlement impacts, such as grazing and fire regimes have also been implicated (Gillespie *et al.* 1995). Recent evidence from North America (Kiesecker *et al.* 2001) suggests that synergistic affects of several processes may cause the decline of some amphibian species. In particular, Kiesecker *et al.* (2001) have shown a pattern whereby climate change has reduced water levels at some oviposition sites, causing high mortality of embryos by increasing their exposure to UV-B radiation (which is increasing due to ozone depletion) and, consequently, increasing embryo vulnerability to infection by pathogens.

Table 2. Reptile taxa recorded in each broad habitat type during surveys (pooled data from all sites). Taxa recorded off-site are not shown (therefore numbers of many taxa do not accord with Table 1, which includes taxa detected incidentally in some regions). Numbers indicate the number of individuals recorded in each habitat type. See text for definitions of broad habitat types. Frogs are not included, as aural detection often means the call emanated from outside the habitat type being surveyed. Habitat key: Bog, Bog; Cleared/dist, Cleared/disturbed; Grassland, Grassland; Heathland, Heathland; MD W'd, Montane Dry Woodland; ROS H MOS, Rocky Outcrop Shrub/Heathland Mosaic; Rocky G'd, Rocky Grassland; Snow G W'd, Snow Gum Woodland.

Species	Common Name	Bog	Cleared/ dist	Grass land	Heath land	MD W'd	ROS/H Mos	Rocky G'd	SnowG W'd
Austrelaps ramsayi	Highland Copperhead	4	-	5	-	-	-	-	-
Drysdalia coronoides	White-lipped Snake	-	-	-	2	-	-	3	-
Bassiana duperreyi	Eastern Three-lined Skink	-	1	-	-	-	-	1	-
Egernia sp.	Undescribed *Egernia*	-	-	-	-	-	-	2	-
Egernia saxatilis intermedia	Black Rock Skink	-	-	-	-	-	2	-	-
Eulamprus kosciuskoi	Alpine Water Skink	22	-	-	1	-	-	-	-
Eulamprus tympanum	Southern Water Skink	29	13	31	-	12	-	-	20
Niveoscincus coventryi	Coventry's Skink	-	-	-	-	2	-	-	-
Pseudemoia cryodroma	Alpine Bog Skink	5	-	-	4	-	-	-	11
	uncertain taxonomy	4	-	-	-	-	-	-	-
Pseudemoia entrecasteauxii	Southern Grass Skink	21	15	2	5	-	-	1	47
Pseudemoia pagenstecheri	Tussock Skink	11	11	9	30	-	-	66	4
Pseudemoia spenceri	Spencer's Skink	-	2	-	-	16	-	-	-
Pseudemoia sp.	Unidentified Grass Skink	-	1	-	2	1	-	-	6
Unidentified scincid		9	22	11	16	7	-	10	29

Gillespie *et al.* (1995) suggested that the following threatening processes are affecting populations of the Alpine Tree Frog:

- trampling of habitat by cattle and possibly feral horses is likely to destroy Alpine Tree Frog breeding habitat;
- the construction and management of hydro-electric facilities in some areas has reduced the number of breeding sites available to the subspecies;
- ski resort development is likely to affect the taxon adversely through modification of habitat;
- due to its restricted high altitude distribution, this frog is likely to be susceptible to climate change associated with the enhanced greenhouse effect;
- other potential threats include development for recreational infrastructure and associated roading, and the impact of wildfire.

Structural complexity of habitat has been cited as a critical requirement for many reptile species and communities (e.g. Brown and Bennett 1995; Hadden and Westbrooke 1996; Brown 2001). Grazing and trampling by stock in the alpine region affects habitat complexity through (1) direct removal of vegetation, (2) destruction of structural components in the ground layer, and (3) soil compaction (Figs 1 and 2). As such, grazing and trampling by stock may represents a significant threat to a range of the region's herpetofauna. During the present study gross damage caused by cattle grazing (typified in Figs 1-4) was noted in all areas where grazing persists. Soil erosion and vegetation damage associated with grazing have been listed as threatening processes under the FFG, and as threats to specific taxa and communities in Action Statements prepared for:

- Alpine She-oak Skink (Clemann in press);

Fig. 1. Alteration of vegetation structural complexity by cattle grazing and trampling on the Howitt Plains. Heavy grazing and trampling inside the fenced area has profoundly modified the structural integrity of the tussock grassland.

- Alpine Water Skink (Meredith *et al.* in press); and
- Alpine Bog Community (NRE in prep.).

Similarly, soil erosion and vegetation damage associated with grazing are the primary processes currently threatening the Alpine Bog Community, Alpine Snowpatch Community and Fen (Bog pool) Community, all of which have been listed as threatened on Schedule 2 of the FFG.

The Alpine Water Skink is restricted to alpine sphagnum mossbed-heath associations (that forms 'bog' and some 'heathland' habitat as defined in the present study) along drainage lines and small streams. This habitat type is particularly susceptible to damage by cattle seeking water and grazing on the palatable sedge *Carex gaudichaudiana* (McDougall 1982, 1989; NRE in prep.). Severe habitat degradation caused by grazing and trampling has been noted at several sites where this lizard occurs (Meredith *et al.* in press; pers. obs.; Fig. 3). Whilst cattle typically only graze on the sedge in late summer (van Rees 1984), Mc Dougall (1989) found that this short exposure to cattle was sufficient to severely damage bog margins. Evidence of extensive trampling of this habitat by cattle is obvious in all areas where cattle graze in the Victorian alps (Wahren *et al.* 1999; pers. obs.). This damage may eventually exclude the Alpine Water Skink from these habitats. Other authors (Coventry and Robertson 1980; Mansergh 1982) have also highlighted this threat to the habitat of the Alpine Water Skink.

The Alpine Water Skink occurs in the stream/bog system along Nelse Creek, north-east of Falls Creek. Within these bogs the lizards use the cornice-like sphagnum overhanging the water as basking sites. When approached, they frequently drop from this overhang into the water and retreat beneath the overhang to avoid capture. This sphagnum margin is usually destroyed by cattle seeking water and fodder (NRE in prep.; pers. obs.; Fig. 4). McDougall (1989: 8) notes that 'the growing edge of the layer bordering pools is most susceptible to dislodgment and destruction by trampling'. Trampling is likely to destroy a vital habitat component for these lizards. The Alpine Water Skink has been recorded on the Bogong High

Plains both north of Rocky Valley Storage, where grazing has been excluded since 1991, and south of this dam where grazing continues. During the present study we detected this species in bog habitat in this northern area, but did not detect it in the currently grazed areas to the south. Further work is needed to compare this species' persistence and abundance in these areas. Such work will further illuminate the Alpine Water Skink's response to grazing, and its response to removal of grazing.

Less obvious than the highly visible damage stock often cause to bogs, is alteration to the hydrology of stream and bog systems caused by trampling. This impact can result in channelling and resultant lowering of the water table (LCC 1982). Bog systems and the peat soils derived from them are dependent on a high water table. As these peat soils dry out they become susceptible to erosion; thus grazing within these zones causes high levels of damage leading in the past to these areas being progressively withdrawn from grazing (LCC 1982). Of the broad habitat types surveyed for this study, bog was the most species rich for reptiles, and is probably the most threatened habitat in the region. The impacts to resident herpetofauna of this habitat degradation have not been quantified, but may be severe.

The Alpine She-oak Skink was not recorded during this study. This cryptic skink, which may be common at some localities, is often difficult to detect, and detection may require the right weather conditions (P Robertson pers. comm.). Schulz and Mansergh (1997) note the uncertainty associated with detection of this species; searches by these authors in the same places in different years have yielded considerably different results. This species has been recorded at only three broad localities within Victoria, two of which are in alpine resorts (in the vicinity of Mt Hotham and Falls Creek Alpine Resorts), where its habitat is subject to ongoing disturbance due to recreational activities and slashing of native vegetation during grooming of ski runs (Schulz *et al.* 1995; Schulz and Mansergh 1997; Clemann in press; D Heinze pers. comm.). Slashing may be sufficient to destroy the structural integrity of Alpine She-oak

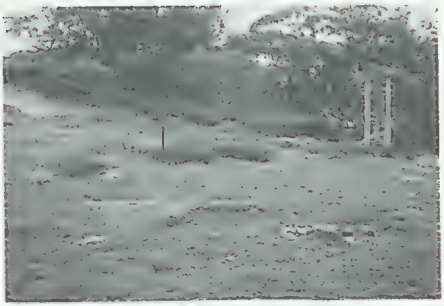

Fig. 2. Alteration of vegetation structural complexity by cattle grazing and trampling in the Mt Stirling area. The area in the top of the photograph is a cattle exclusion zone. The structure of the vegetation in the foreground (outside of the cattle exclusion zone) has been profoundly modified by cattle grazing.

Skink habitat (D Heinze pers. comm.). Habitat of this species at Basalt Hill near Falls Creek is also subject to cattle grazing in summer, as is the third broad locality at which it has been detected (Lankeys Plain). Cattle graze on species of tussock grass that are important components of Alpine She-oak Skink habitat (van Rees 1984).

The Alpine Bog Skink occurs in grassland, Snow Gum woodland and heathlands, yet is most abundant in bogs and boggy creeks (Hutchinson and Donnellan 1992; pers. obs.). Its occurrence in these habitats is often marginal, overlapping with the Tussock Skink and Southern Grass Skink. Despite this sympatry, the Alpine Bog Skink tends to occur in wetter microhabitats than the Tussock Skink, and in more open areas than the Southern Grass Skink (Hutchinson and Donnellan 1992; pers. obs.). The occurrence of the Alpine Bog Skink on Davies Plain, close to the New South Wales border, suggests that it may yet be detected in similar habitat over the border.

The Southern Grass Skink and the Tussock Skink were frequently recorded during this study; each was recorded in six habitat types, within six and seven of the broad study areas, respectively. This reflects their widespread and abundant nature in the alpine region. The taxonomy of lizards in this genus has only recently been clarified by using eletrophoretic, karyotopic and morphological data (Hutchinson and Donnellan 1992).

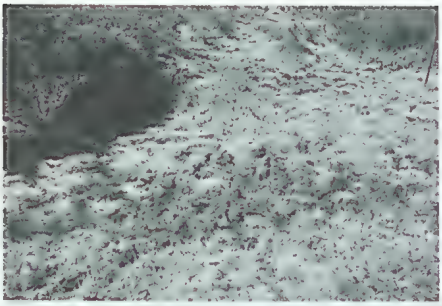

Fig. 3. Damage in bog habitat on Davies Plain caused by cattle trampling. Nearby undamaged habitat is occupied by the Alpine Water Skink.

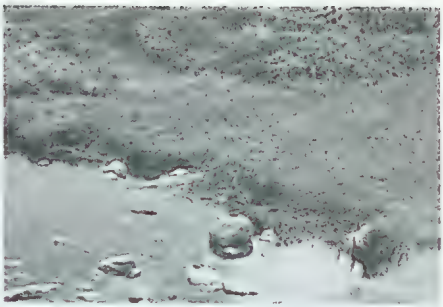

Fig. 4. Damage caused by cattle to the margin of a wet area that was once a bog/stream complex on the Bogong High Plains.

Unfortunately, considerable variation and overlap in colouration and morphology exists between alpine taxa within this genus (particularly *P. pagenstecheri* and *P. cryodroma*), confounding the identification of some specimens in the field. Tentative identification of some specimens collected during this study required confirmation by Dr Mark Hutchinson (South Australian Museum). In the absence of further electrophoretic testing, the identification of some specimens (notably those from Mt Buffalo) remains uncertain.

Davies Plain was the most species rich (10 taxa) of the broad areas surveyed in this study. Threatened species recorded in this area included the Alpine Water Skink and Alpine Bog Skink (historically, the Alpine Tree Frog also occurred on this plain). The unidentified *Egernia* species recorded on this plain (and throughout the alpine areas) are significant fauna, and are likely to be candidates for future listing as threatened taxa (P Robertson pers. comm.). Thus, Davies Plain is of particular value for threatened alpine herpetofauna. Despite this, the area remains subject to cattle grazing, and is one of the strongholds for feral horses in the Victorian alps. Many horses were observed on this plain during two days of fieldwork. Whilst horses on the Bogong High Plains represent an isolated population, those on Davies Plain are members of a population extending from Thredbo in New South Wales to the Buchan River in Victoria (M Walters pers. comm.). Both cattle and horses are causing considerable damage to bog habitat on Davies Plain, suggesting that their management should be an urgent priority in this area.

There is a growing body of evidence that cattle grazing has a significant detrimental effect on alpine habitats (references cited throughout this discussion) and, consequently, a deleterious effect on terrestrial alpine fauna. In particular, grazing has a devastating impact on wet vegetation associations in alpine areas that are important habitat for the Alpine Bog Skink, and vital for the Alpine Water Skink, and Wahren *et al.* (1999: 165) note that 'continued grazing by cattle is not compatible with the conservation objectives for this vegetation type'. This damage has long been recognised (Costin 1958), and it is now clear that grazing in alpine areas places at considerable risk the conservation value of the region. The only way of ensuring the continued existence of several terrestrial vertebrates and the integrity of some plant species and communities may be to control densities of cattle and horses, or remove them from certain areas. Williams *et al.* (1997) summarised the damage caused by cattle grazing on the Bogong High Plains (including the facilitation of weed invasion), and recommended the removal of cattle from these plains. The fact that cattle have been successively excluded from parts of the high plains (e.g. northern Bogong High Plains, Mts Bogong, Hotham and Feathertop) for conservation purposes is indicative of the damage stock have caused in these areas. The revegetation and recovery of areas after cattle or other stock have been removed is an extremely slow process owing to the harsh nature of the

alpine climate and the low mineral content of soils (Downes 1961; Bridle and Kirkpatrick 1999). In fact, some alpine wetlands may take decades or even hundreds of years to recover from the impact of livestock incursion (Wahren *et al.* 1996). The last grazing leases were withdrawn from Kosciuszko National Park in 1969, but rehabilitation of habitat damaged by cattle is still needed today (Scherrer and Pickering 2001). Consequently, grazing pressure should be eliminated from these areas sooner rather than later. Implicit in the need to remove grazing from some areas is the need for habitat rehabilitation. A major consideration of such rehabilitation is that the costs of these activities are usually borne by organisations different from those responsible for the damage. Thus the benefits of grazing go to private individuals, whilst the cost of reparation is borne by the public (Scherrer and Pickering 2001).

The impact of introduced predators such as foxes and cats on alpine herpetofauna has not been quantified; however, observations of foxes in some alpine areas has shown that they prey on a range of reptile species, including the Alpine Water Skink (R Martin pers. comm.). Such impacts are likely to be particularly devastating for species with very small geographic ranges (such as the Alpine She-oak Skink), those with a high degree of habitat specificity, particularly those occupying narrow, often linear habitats (such as the Alpine Water Skink), and those whose populations are diminished or stressed due to other threatening processes. Similarly, domestic pets may be a threat to the Alpine She-oak Skink in the vicinity of the Mt Hotham and Falls Creek villages.

Climate change (i.e. 'global warming') may pose a considerable threat to alpine organisms. Whilst some taxa may be able to migrate to higher altitudes to maintain their preferred climate, others will not, and species already at the top of their possible altitudinal distribution are likely to be replaced by other species moving up (Hughes and Westoby 1994). As climate conditions change, generalist species may have a greater capacity to occupy, reinvade or outcompete specialist congeners (Bennett *et al.* 1991).

Acknowledgements

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Wild Solutions: How Biodiversity is Money in the Bank

by Andrew Beattie and Paul Ehrlich

Publisher: *Melbourne University Press, 2001. 239 pp. ISBN 0 522 84986 5. $49.95.*

Loss of biodiversity – the wealth of natural variety on our planet – is one of the greatest concerns of modern times. In a world driven largely by pragmatic decisions, evaluating and communicating the richness and variety of living organisms is an important basis for conservation. *Wild Solutions* is written by two eloquent conservation ecologists to help convey the potentially tangible values of organisms that are most commonly regarded as passengers in wider conservation endeavour, namely the invertebrates, microorganisms and 'lower' plants. Beattie and Ehrlich

demonstrate the immense importance of these organisms, and their incredible spectrum of largely unexplored benefits to (and uses for) humanity, together with their variety and vital roles in ecological sustainability. Collectively, invertebrates have 'solved' many of the problems of survival in complex or extreme environments that still challenge human ingenuity, and studying how they have done this may provide valuable clues for human wellbeing. The breadth of examples used is impressive, and the simplified language renders the book accessible to general readers whose knowledge of invertebrates may be limited. Christine Turnbull's clear line drawings of many of the organisms discussed are also helpful and appealing.

Indeed, from some points of view, the efforts to write in very general terms are occasionally frustrating, in that highly complex scientific stories are presented very simplistically and the sense of wonder we should feel at their intricacy tends to 'get lost'! The information presented here is too important to be taken for granted. Nevertheless, the reader will surely appreciate the authors' attempts to summarise such a vast compass in this form. Their key message is that we must be induced to value and develop the *concept* of 'natural capital' before its *value* is destroyed, and that natural capital is the very organisms that we usually overlook or deride. The loss of biodiversity can be attributed largely to three categories of human activity: overpopulation, overdevelopment and overexploitation. One important message (p. 224) is that 'we can never predict what species or populations are going to be useful or even desperately important in the future', and consequently the arguments sometimes advanced on redundancy of many taxa (so that these are then functionally dispensable in terms of pragmatic human values) are very poorly founded in present knowledge. Curtailing losses of taxa from human activities may well be the key to our future survival.

The book consists of 13 main chapters, and a list of further reading, which usefully augments the main content. Chapter 1 commences with an apt quotation from Antonie van Leewenhoek (1632-1723) 'All we have yet discovered is but a trifle in comparison with what lies hid in the great treasury of nature', a sentiment acknowledged by many modern commentators and sobering in relation to the assumptions we tend to make in our dealings with life on earth. The history of discovery of invertebrates and microorganisms continually shows the uncertainties we face in trying to define their richness even within an order of magnitude. More specific themes are then developed, covering most major ecosystems, and stressing the uniqueness and intricacies of the interactions between taxa and the ways in which study of living organisms provides lessons for human technological enterprise in virtually any field of endeavour – including pharmaceutical/medical benefits, robotics, chemical engineering (biomimicry), biological monitoring, recycling materials, and the wide variety of other ecosystem services. Use of bacteria to help clear up diesel spills in soils or feeding on old car tyres and noxious agricultural chemicals; of bull ant secretions as antibiotics; of spider silks as models for lightweight body armour; of velvetworm 'spit' as rapid-setting glue and correspondingly rapid solvents for it; and of tardigrades as producers of antifreeze are amongst the numerous tantalising issues discussed. The potential list of such benefits is both endless and fascinating.

Much of this book induces an increasing sense of wonder at the possibilities for people to 'capitalise' on such values of natural biodiversity, and the urgency to do so. The authors convey powerfully that we lose biodiversity at our peril, and the book is a valuable contribution to the conservation debate. Read it, and spread its messages as widely as you can!

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The Mammals of Parker River Inlet, Otway National Park

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Abstract
Studies of small mammals at Parker River Inlet from 1985-95 have demonstrated the presence of ten species of small mammals. Trapping, spotlighting and incidental sightings have shown that a further 18 species of mammals occur within an area of 200 ha. *Pseudomys fumeus* and *Antechinus minimus*, recorded in this survey, are rare and restricted in Victoria. The species richness of the area is related to the heterogeneity of the vegetation, with twelve vegetation types being identified in the study area. The occurrence of the more abundant small mammals, *Rattus fuscipes, Rattus lutreolus, Mus musculus* and *Antechinus swainsonii*, is correlated with vegetation structure and floristics. Causes of fluctuations of the populations of the exotic species *M. musculus* and *Rattus rattus* are considered. Management recommendations, which reflect the high significance of faunal habitat in the area, are made with the aim of minimising human impact. (*The Victorian Naturalist* **119** (2), 2002, 60-68)

Introduction

Botanically, the Otways, in particular the Cape Otway/Parker River area, is considered significant as an isolated western extremity of a vegetation type much more extensive in eastern Victoria and Tasmania (Carr 1971). Preliminary surveys in 1982 and 1983 at Parker River Inlet, located in the southwest corner of the main block of Otway National Park (Fig. 1), revealed the presence of six species of small mammals, and sufficient interest was generated to warrant a more extensive, long-term study.

At the mouth of Parker River, sandstone cliffs give way to dune limestone cliffs, outcrops and stable dunes (Fig. 2). The lower course of Parker River is aligned along a fault. The estuarine sector has developed where the fault zone crosses the coast, allowing the stream to cut a wider valley in the fractured rock. The estuarine sector is short and largely filled by a tidal delta of in-washed sand (Rosengren 1984). Parker River enters the estuary over a series of cascades and small falls. Elevated areas receive abundant rains, falling mainly between autumn and early summer. Rainfall at Cape Otway averages 890 mm per annum, but rises to twice this figure on the Parker Ridge. The combination of these elements has resulted in both floristic and structural diversity of vegetation with a great variety of associations being represented within a small area around Parker River Inlet. Data presented relates to an area of 200 ha located either side of the lower reaches of Parker River.

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Methods

Small mammal trapping

A trapping grid was established at Parker River Inlet. It comprised 100 trap locations 20 m apart encompassing an area of approximately 5 ha of diverse topography and vegetation. One trap was placed at each site. Small folding mammal traps 33 × 10 × 10 cm (Elliott Scientific Equipment, Upwey, Victoria) were baited with a mixture of peanut butter, rolled oats and honey. Sites were trapped for three consecutive nights on 14 occasions from April 1985 to October 1988, a total of 4200 trap nights. Traps were cleared and reset each morning. Animals caught were identified, sexed, weighed to the nearest gram and marked with numbered fingerling tags (National Band and Tag Co. No. 1) on the ear.

Recording of other mammal species

From April 1985 to March 1995 incidental observations were made of other mammals occurring in the vicinity of the Inlet within the area shown on Fig. 1. In March 1989 a Harp Trap was set at the bridge over Parker River, 1 km from the inlet, for three consecutive nights to trap insectivorous bats.

Vegetation assessment

At each trap site on the small mammal grid, the structure and floristics of the vegetation were assessed and related to the occurrence of the more frequently trapped species. The vegetation of the surrounding area was also surveyed.

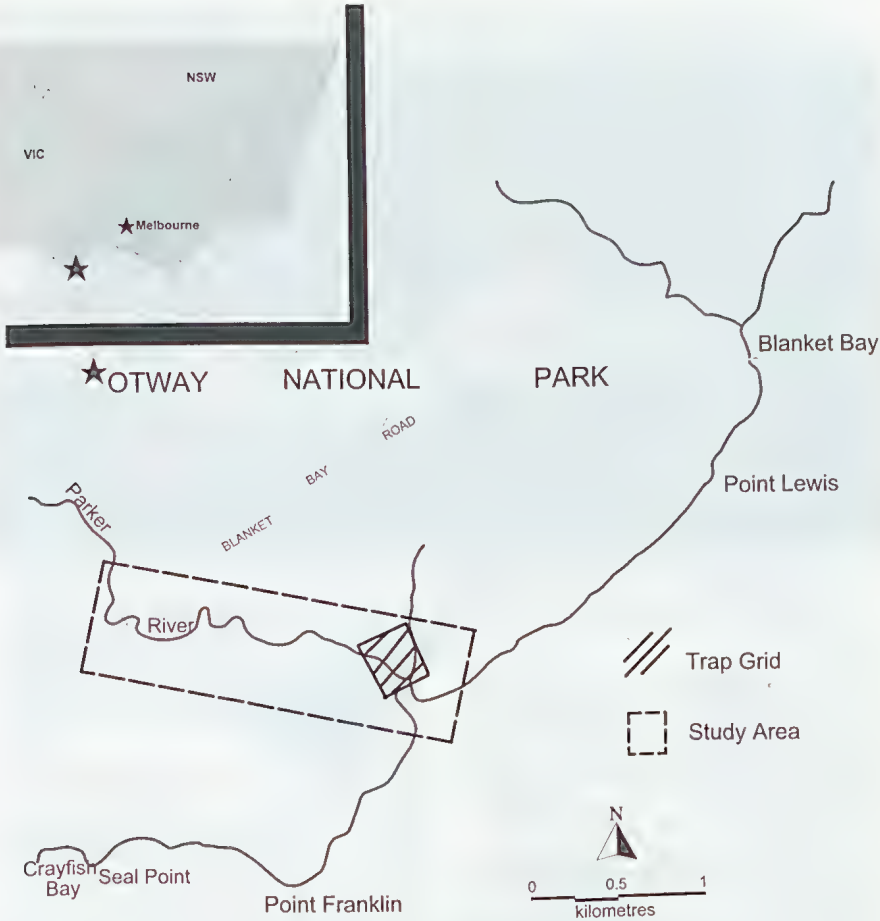

Fig. 1. Location of study site at Parker River, Otway National Park, Victoria.

Results

Vegetation

Eleven vegetation associations were identified in the area around the lower reaches of Parker River (Fig. 3). Seven of these were represented within the trapping grid and are marked *. Taxonomy is according to Ross (2000).

**Eucalyptus globulus* tall open-forest (Gully)

Tall open forests dominated by Blue Gum *Eucalyptus globulus*, with a range of associated shrub species including Hazel Pomaderris *Pomaderris aspera*, Prickly Currant-bush *Coprosma quadrifida* and Privet Mock-olive *Notelaea ligustrina*. The ground layer was dominated by ferns including Common Maidenhair *Adiantum aethiopicum*, Hard Water-fern *Blechnum procerum*, Common Ground-fern *Culcita dubia* and Spreading Fan-fern *Sticheris lobatus*.

Eucalyptus obliqua open-forest

Open forest dominated by Messmate *E. obliqua*, to 20 m.with an understorey of shrubs to 2m. Shrub species include Heath Tea-tree *Leptospermum myrsinoides*, Lance Beard-heath *Leucopogon lanceolatus*, Prickly Moses *Acacia verticillata* and Large-leaf Bush-pea *Pultenaea daphnoides*.

Fig. 2. Parker River Inlet, Otway National Park, Victoria.

**E. obliqua/E. globulus* open forest (Open Forest)

Open forest dominated by *E. obliqua* and *E. globulus*. An open understorey of *Poa* spp. with Austral Bracken *Pteridium esculentum*, Spiny-headed Mat-rush *Lomandra longifolia* subsp. *longifolia*, Snowy Daisy-bush *Olearia lirata*, *A. verticillata* and Sweet Bursaria *Bursaria spinosa*.

*'Otway messmate' low open-forest (L. Open Forest)

Low open forest of the hybrid Otway Messmate with an understorey dominated by Tussock Grass *Poa labillardieri*, *L. longifolia* subsp. *longifolia*, and *P. esculentum*. Scattered shrubs include Coast Beard-heath *Leucopogon parviflorus* and Silver Banksia *Banksia marginata*.

Eucalyptus viminalis woodland

On undulating stabilised dunes between the lighthouse road and Blanket Bay Road occurs a woodland of Manna Gum *E. viminalis* with a sparse shrub layer of *A. verticillata* and *B. spinosa*, with a ground layer dominated by *P. labillardieri* and *L. longifolia*.

Leptospermum continentale/Melaleuca squarrosa tall closed-shrubland

In more or less sheltered coastal gullies to the west of Parker River a dense closed shrubland of Scented Paperbark *Melaleuca squarrosa* and Prickly Tea-tree *Leptospermum continentale* occurs. The ground layer is sparse or absent.

Closed heathland

On flat poorly drained areas along the Blanket Bay Road a closed heath of Scrub Sheoak *Allocasuarina paludosa*, Dwarf Sheoak *A. pusilla*, Prickly Tea-tree *L. continentale* and *B. marginata* occurs. Other associated species include Austral Grass-tree *Xanthorrhoea australis*, Common Heath *Epacris impressa* and members of the Restionaceae. There is an occasional overstorey of Bog Gum *Eucalyptus kitsoniana*.

*Low open heathland (Heath)

Areas on the dune limestone cliffs are dominated by *L. parviflorus*. This varies from small stunted shrubs less than 1 m tall in exposed sites to 3 m in more sheltered situations. *Leucopogon parviflorus* was generally an overstorey to either *P. labillardieri* or Buffalo Grass *Stenotaphrum secundatum* but, where associated with *L. continentale*, Manuka *Leptospermum scoparium* and *B. marginata*, an almost impenetrable thicket existed, excluding any ground layer. Scattered stands of Drooping Sheoak *Allocasuarina verticillata* also occur.

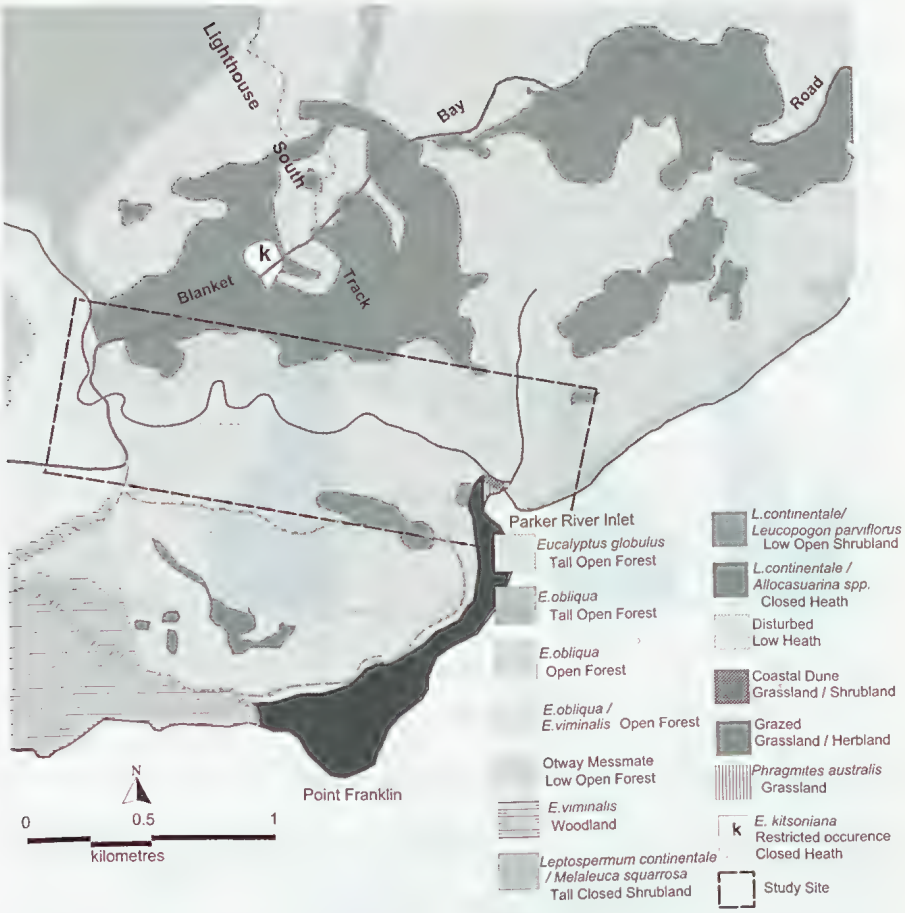

Fig. 3. Vegetation communities of Parker River, Otway National Park, Victoria.

*Coastal dune complex (Dune)

Marram Grass *Ammophila arenaria* and Hairy Spinifex *Spinifex hirsutus* provide the major stabilizing vegetation on the seaward dunes. Associated species include *P. esculentum* and Knobby Club-rush *Isolepis nodosa*. Sea Rocket *Cakile edentula* is apparently the first species to colonise the sand of the open beach but this may be the result of large-scale sand movements.

**Phragmites australis* grassland (Phrag)

Common Reed *Phragmites australis* dominates a stretch alongside Parker River between the waterfall and the beach. *Poa labillardieri* occurs with it except where inundated with water.

*Tussock grassland (Grass)

Poa labillardieri, forms dense stands to 1 m in height with *S. secundatum*. *Poa labillardieri* was the dominant species in low-lying areas, whereas *S. secundatum* occurs as the dominant species on level areas between the dune system and the first dune limestone cliff. In this situation the Buffalo Grass has been grazed by roaming cattle to produce a low, even lawn, interspersed with other grass species such as Hare's Tail *Lagurus ovatus*, Slender Tussock-grass *Poa tenera*, Cocksfoot *Dactylis glomerata*, Yorkshire Fog *Holcus lanatus* and Tall Fescue *Festuca arundinacea*.

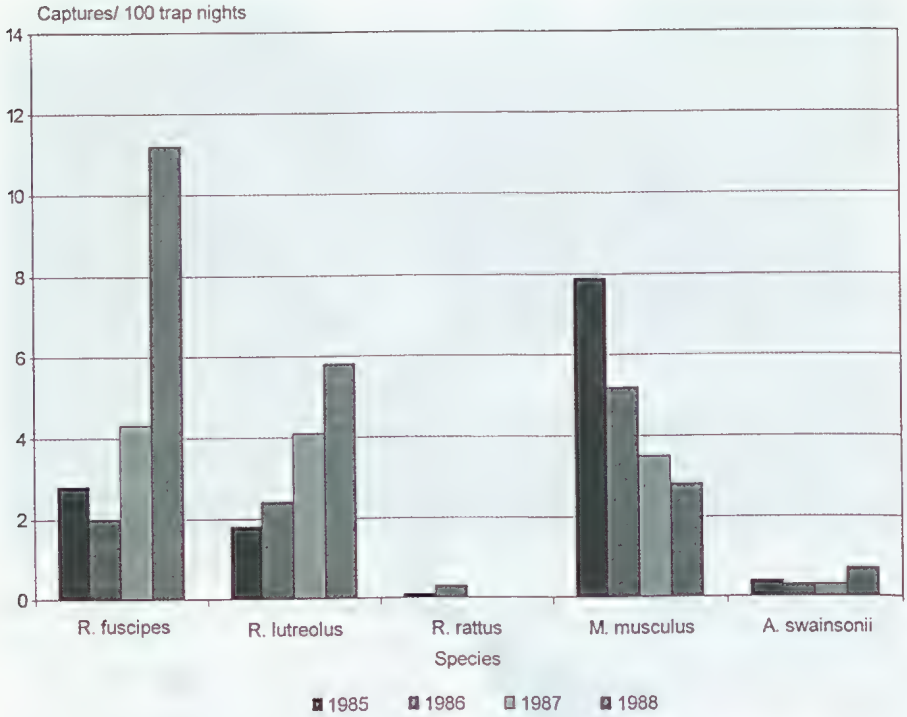

Fig. 4. Mammal captures/100 trap nights, Parker River Inlet, Victoria.

Small mammals

Nine species of small mammal were recorded: Swamp Rat *Rattus lutreolus*, Black Rat *Rattus rattus*, Bush Rat *Rattus fuscipes*, Smoky Mouse *Pseudomys fumeus*, House Mouse *Mus musculus*, Agile Antechinus *Antechinus agilis*, Swamp Antechinus *Antechinus minimus*, Dusky Antechinus *Antechinus swainsonii* and White-footed Dunnart *Sminthopsis leucopus*. A single dead specimen of Southern Brown Bandicoot *Isoodon obesulus* was also found. Relative abundance of the more frequently occurring species over the four years based on captures per 100 trap nights is shown in Fig. 4. The occurrence of the small mammal species in the seven vegetation types represented on the trapping grid is shown in Table 1.

Other mammals

During the period of the study incidental observations of ten larger mammal species were made together with five bat species trapped in March 1989 (Table 2).

Discussion

Small mammals frequently captured at Parker River Inlet were *R. fuscipes*, *R. lutreolus*, *M. musculus* and *A. swainsonii*. *Pseudomys fumeus*, although only trapped twice is a significant record for the area since it has been infrequently recorded in the Otways. *Antechinus minimus* is listed as rare in Victoria because it is found only in small isolated populations. There are only two previous records of *Sminthopsis leucopus* from the Cape Otway area. The appearance and later disappearance of a population of *R. rattus* is of interest and may be related to changes in use in the area.

Rattus fuscipes is a widespread and common species, being found in sub-alpine woodland, coastal scrub, eucalypt forest and rainforest. It is nocturnal, preferring

The Victorian Naturalist

Index to

Volume 118, 2001

Compiled by KN Bell

Authors

Adams R, Simmons D and Lewis C, 16
Ahern L, 285
Archbold NW, 66 (Tribute), 178, 234
Ashton DH, 321
Barker R, 61 (book review)
Bell KN, 101 (book review)
Bock P, 256
Boyd S, Coventry AJ, Dixon J, Gomon M, O'Loughlin M, Poore G, Walker K and Yen AL, 242
Broadberry J, 64 (book review), 65 (book review)
Broome L, Heinze D, Johnston S and Green K, 112
Burgess DR and Wright MF, 117
Butcher BW, 226
Carkeek M, 151
Clemann N, 30 (book review)
Conole L and Mac Nally R, 56
Coventry AJ, Dixon J, Gomon M, O'Loughlin M, Poore G, Walker K, Yen AL and Boyd S, 242
Dann P, Jessop R and Healy M, 76
Darragh TA, 160
Di Stefano J, 46
Dixon J, Gomon M, O'Loughlin M, Poore G, Walker K, Yen AL, Boyd S and Coventry AJ, 242
Earp C, 82
Editors, *Vic. Nat.*, 107, 159, 233
Fleming A, 210
Fletcher RJ, 27 (book review)
Gerdtz WR, 231
Gibson M, 102 (book review)
Gillbank L, 297
Gomon M, O'Loughlin M, Poore G, Walker K, Yen AL, Boyd S, Coventry AJ and Dixon J, 242
Green K, Broome L, Heinze D and Johnston S, 112
Grey E, 74, 100
Grey P, 104 (software review)
Healy M, Dann P and Jessop R, 76
Heinze D, Johnston S, Green K and Broome L, 112
Hell AJ, 294
Holland GJ, 123
Houghton S, 314
Jessop R, Dann P and Healy M, 76
Johnston F and Pickering CM, 21
Johnston S, Green K, Broome L and Heinze D, 112
Kasel S, 127
Leary EJ, Parris KM, McDonnell MJ and Williams NSG, 4
Lebel T, 38
Lewis C, Simmons D and Adams R, 16
McCann D, 146, 148, 165, 309, 319
Mace B, 287
McDonnell MJ, Williams NSG, Leary EJ and Parris KM, 4
McLean A and Meagher D, 92
Mac Nally R and Conole LE, 56
Maroske S, 305
May T, 44
Meagher D and McLean A, 92
Milne J and Thies AW, 89
Morton A, 62, (book review), 142 (book review)
O'Brien M, 60 (book review)
O'Loughlin M, Poore G, Walker K, Yen AL, Boyd S, Coventry AJ, Dixon J and Gomon M, 242
Parkin A, 2
Parris KM, McDonnell MJ, Williams NSG and Leary EJ, 4
Pascoe G, 193
Pickering CM and Johnston F, 21
Pickering CM and Scherrer P, 93
Pierson R, 219
Poore G, Walker K, Yen AL, Boyd S, Coventry AJ, Dixon J, Gomon M and O'Loughlin M, 242
Rasmussen C, 200
Sault T, 106 (Tribute)
Scherrer P and Pickering CM, 93
Schleiger N, 29 (Tribute), 266
Seebeck J and Warneke, RM 277
Simmons D, Lewis C and Adams R, 16
Sinclair B, 143 (book review)
Slattery D, 25 (book review)
Stefano J Di, 46
Thies AW and Milne J, 89
Traill A, 58, 59
Walker K, Yen AL, Boyd S, Coventry AJ, Dixon J, Gomon M, O'Loughlin M, and Poore G, 242
Warne MT, 283
Warneke RM and Seebeck J, 277
Weste G, 140
Wilkinson I, 186
Williams NSG, Parris KM, McDonnell MJ and Leary EJ, 4
Wright MF and Burgess DR, 117
Yen AL, Boyd S, Coventry AJ, Dixon J, Gomon M, O'Loughlin M, Walker K and Poore G, 242

Birds
Eudyptula minor, at sea, Western Port, 76
Little penguins, at sea, Western Port, 76
McCoy-Gould correspondence, 210
Red-chested Button-quail, identity, ecology, status, 56
Turnix pyrrhothorax, identity, ecology, status, 56

Book Reviews
Birds of French Island Wetlands, D Quinn and G Lacey (M O'Brien), 60
Celebrating our Parks: Proceedings of the First Australian Symposium on Parks History, ed E Hamilton-Smith (D Slattery), 25
Common Australian Fungi: A Bushwalkers Guide, T Young (R Barker), 61
Field Guide to the Orchids of NSW and Victoria, 2 ed, T Bishop (J Broadberry), 64
Flora of Australia, v 48: Ferns, Gymnosperms and Allied Groups, (M Gibson), 102
Guide to Squid, Cuttlefish and Octopuses of Australasia, M Norman and A Reid (K Bell), 101
Kosciuszko Alpine Flora, 2 ed, AB Costin, M Gray, GJ Totterdell and DJ Wimbush (RJ Fletcher), 27
Native Orchids of Southern Australia: A Field Guide, D and B Jones (J Broadberry), 65
Nature Photography, K Griffiths (A Morton), 142
Pythons of Australia: A Natural History, G Torr (N Clemann), 30
Wildflowers of the Brisbane Ranges, C and M Trigg (A Morton), 62
Wildflowers of Victoria, M Corrick and B Fuhrer (B Sinclair), 143

Botany
Achillea millefolium, weed threat, Australian Alps, 21
Allocasuarina luehmannii, galls and mistletoes on, 117
Alpine vegetation, grazing, tourism, climate effects, 93
Australian Edelweiss at Mount Hotham, 2
Buloke, galls and mistletoes on, 117
Eucalyptus crenulata, Buxton Silvergum Reserve, 16
Ewartia nubigena at Mount Hotham, 2
Dieback disease, impact, Mount Stapylton, 46
FUNGIMAP, target species notes, 44
Leafy liverwort, Yarra Ranges NP, 92
Mistletoes, galls on Buloke, 117
Moss collections, Lord Howe Island, addendum, 89
Native grasslands, potential freeway impact, 4
Pedinophyllum monoicum in Yarra Ranges, NP, 92
Phytophthora cinnamomi, Mount Stapylton, 46
System Garden, University of Melbourne, 193
Truffles, native Australian, 38
Yarrow, weed threat, Australian Alps, 21

Entomology
Agrotis infusa, arsenic carriers, 112
Ant behaviour, 100
Bogong moths, arsenic carriers, 112
Galls and mistletoes on Buloke, 117
Leptopius sp. c.f. *L. gravis*, Simpson Desert, 74
Weevil, large, Simpson Desert, 74

Geology
Black coal McCoy-Clarke dispute, 219
Cranbourne meteorites, fate of, 305
Geological time scale, 150
Tanjilian (Early Devonian) fossils, Dungaree Creek, 82

Honours
David Ashton OAM (Gretna Weste), 140
Lyle Courtney OAM (The Editors), 107
Gwen Elliot AM (FNCV), 141
Roger Elliot AM (FNCV), 141

Localities
Australian Alps, Yarrow weed threat, 21
Buxton Silver Gum Reserve, historic changes, 16
Dungaree, Creek, Central Victoria, Tanjilian fossils, 82
Hume Freeway-F2 link, impact on grasslands, 4
Kosciuszko NP, grazing, tourism, climate effects on, 93
Lord Howe Island, moss collection in MEL, addendum, 89
Mount Hotham, Australian Edelweiss, 2
Mount Macedon, McCoy's property at, 319
Mount Stapylton, Grampian NP, dieback at, 46
Northern Victoria, Red-chested Button-quail, 56
Snowy Mountains, Bogong moths as arsenic carriers, 112

Victorian Alps, Bogong moths as arsenic carriers, 112
Western Port, Little penguins at, 76
Wimmera, galls and mistletoes on Buloke, 117
Yarra Ranges NP, leafy liverwort in, 92
Yellingbo Nature Conservation Reserve, human and natural impacts on, 127

McCoy, Frederick
Animal acclimatization society, 297
Antievolutionism, 226
Birds, Gould correspondence, 210
Black coal dispute with Clarke, 219
Brachiopoda, 178
Bryozoa, 256
Cranbourne meteorites, fate of, 305
The late F McCoy (extract *Vic. Nat.* 1899), 276
FNCV, 314
Graptolites, 266
Grave, McCoy's, 304
Ichthyosaur, 294
Irish years, 160
McCoy society, 321
Mammals, McCoy's, 277
Name, spelling of, 234
National Museum of Victoria, 200
Naturalist tradition, 309
Ostracoda, 283
Overview of his life, 151
Prodromus of Zoology of Victoria, 242
Property at Mount Macedon, 319
Snake, Western Brown, 285
Stratigraphic palaeontology, 165
System Garden, University of Melbourne, 193
Tasmanian devil, 231
Thylacoleo, 287
Timeline of his life, 148
University of Melbourne, 186

Mammals
McCoy's mammals, 277
Petaurus norfolcensis, opportunistic vertebrate predation by, 123
Squirrel glider, opportunistic vertebrate predation by, 123
Tasmanian devil, 231
Thylacoleo, 287

Miscellaneous
100 years ago, 15, 105, 140
Animal acclimatization society, 297
Antievolutionism, McCoy, 226
Australian Ornithological Conference, 43
Flora and Fauna Guarantee Act 1988, 91
FNCV and McCoy, 314
FUNGIMAP National Conference, 45
Geological timescale, 150
Human and natural impacts, Yellingbo Nature Conservation Reserve, 127
International Ornithological Conference, 126
International Year of Mountains 116
Introduction, McCoy Special Issue, 146
Irish years, McCoy, 160
McCoy grave, 304
McCoy society, 321
Name, spelling of McCoy, 234
National Museum (extract *Vic. Nat.*), 209
National Museum of Victoria, 200
Naturalist tradition, 309
Overview of McCoy's life, 151
Prodromus of Zoology of Victoria, 242
McCoy's property at Mount Macedon, 319
Timeline of McCoy's life, 148
University of Melbourne and McCoy, 186
VFNCA Annual Camp, 141

Palaeontology
Brachiopoda, 178
Bryozoa, 256
The late F McCoy (extract *Vic. Nat.* 1899), 276
Graptolites, 266
Ichthyosaur, 294
Ostracoda, 283
Stratigraphic palaeontology, 165
Tanjilian (Early Devonian) fossils, Dungaree Creek, 82
Tasmanian devil, 231
Thylacoleo, 287

Reptiles
Black snake feeding, 59
Lampropholis guichenoti, mating behaviour, 58
Pseudechis porphyriacus, feeding, 59
Skink mating behaviour, 58

Software Review
Compendium of FUNGIMAP Target Species, V. 1.0 [CD-ROM] (P Grey), 104

Tributes
Ilma Dunn, 110
Stefanie Rennick (T Sault), 106
John Paul Stewart (N Schleiger), 29
George Anthony Thomas (NW Archbold), 66

Issues 5 and 6 form the McCoy Special Issue

Table 1. Relationship of small mammals to vegetation types. o, not recorded; +, occasional; #, frequent. * denotes exotic species. Taxonomy according to Menkhorst (1995).

	Grass	Phrag	Dune	Heath	L. Open Forest	Open Forest	Gully
Rattus fuscipes	#	#	+	#	#	#	#
Rattus lutreolus	#	#	+	#	+	+	+
**Rattus rattus*	+	+	+	+	o	o	o
Pseudomys fumeus	o	o	o	o	+	+	o
**Mus musculus*	#	#	#	#	#	+	o
Antechinus swainsonii	+	o	o	+	+	+	+
Antechinus agilis	o	o	o	+	+	+	+
Antechinus minimus	+	+	o	o	o	+	o
Sminthopsis leucopus	o	o	o	o	+	+	o

Table 2. Species of larger mammals and bats recorded adjacent to Parker River Inlet. * denotes exotic species.

Species	Evidence	Location
Ornithorhynchus anatinus	Diurnal observation	Parker River
Tachyglossus aculeatus	Diurnal observation	Open Forest
Wallabia bicolor	Diurnal observation	Widespread
Phascolarctos cinereus	Diurnal observation	Woodland
Trichosurus vulpecula	Nocturnal observation	Open Forest
Pseudocheirus peregrinus	Nocturnal observation	Open Forest
Petaurus australis	Nocturnal observation	Tall Open Forest
Petaurus breviceps	Nocturnal observation	Tall Open Forest
Acrobates pygmaeus	Nocturnal observation	Tall Open Forest
Isoodon obesulus	Carcass	Open Forest
**Vulpes vulpes*	Scats, prints	Dunes
Vespadelus darlingtoni	Harp trap	Tall Open Forest
Vespadelus regulus	Harp trap	Tall Open-forest
Chalinolobus morio	Harp trap	Tall Open Forest
Chalinolobus gouldii	Harp trap	Tall Open Forest
Nyctophilus geoffroyi	Harp trap	Tall Open Forest
Falsistrellus tasmaniensis	Harp trap	Tall Open Forest
Hydromys chrysogaster	Cage trap	Parker River
Arctocephalus pusillus doriferus	Diurnal observation	Parker River Inlet

areas where there is dense ground cover. Although non-fossorial, it excavates burrows under stumps, logs, bushes and clumps of grass (Warneke 1971). In spite of having broad habitat preferences (Hall and Lee 1982), several studies have shown it to be associated with dense cover and structually complex vegetation types (Leonard 1970; Warneke 1971; Braithwaite *et al.* 1978). *Rattus fuscipes* has been shown to be adversely affected by fire (Fox 1982) and, in the Otways, it was absent for three years of post-fire succession (Rogers 1991). The results of this study associate *R. fuscipes* with dune complex vegetation with dense ground cover. Thus it appears that friable soils, which provide favourable conditions for burrowing and support a rich microfauna of arthropods and other animals, are a major habitat requirement.

Rattus lutreolus has been described as a rodent of heath, grass or sedge. Catling (1986) pointed out that, whilst *R. fuscipes* is primarily a forest species, *R. lutreolus* is considered to be a wet heath species that inhabits areas of thick vegetative cover. Catling (1986) identified dietary differences as the reason that *R. lutreolus* precedes *R. fuscipes* post-fire. *Rattus lutreolus* is predominantly a herbivore, feeding on sedges, mosses, fungi, some herbs, seeds and insects (Seebeck 1995a), whilst *R. fuscipes* is omnivorous, eating insects and plant material (Seebeck 1995b). *R. lutreolus* was trapped most frequently in the heath and tussock grassland, sites that had a dense ground layer and a generally

sparse overstorey. This species was frequently encountered in the coastal dune complex, often adjacent to the beach.

Mus musculus is an introduced species existing in large populations where appropriate food is available, and is an opportunistic and omnivorous species (Watts and Aslin 1981). Norton (1987) pointed out that at several heathland sites, the species showed clear habitat preferences for similar floristic groups. In dry heathland in north-easten Tasmania captures of House Mice were positively correlated with floristic richness and negatively correlated with vegetation cover less than 50 cm high. Floristically diverse habitats could provide a range of food resources throughout the year, support year-round breeding and result in a rapid population increase. Rapid population growth is well documented for this species (Newsome 1969). *Mus musculus* was most commonly trapped within the heath and low open-forest, this preference perhaps reflecting suitability of the soil for burrowing, or related to plant diversity and the greater range of food sources throughout the year. Data support a significant decline in the population of this species over the four years of the study at Parker River. This may be a result of decline post fire, as has been reported by Newsome (1995). He suggested a decline 3-4 years post-fire together with a return of populations of native rodents. The last fire in this locality, immediately to the north-west of the study area, was at least ten years prior to this study.

Antechinus swainsonii is a small ground-dwelling marsupial. According to Dickman (1995), the preferred habitats of *A. swainsonii* have a dense understorey of fern or shrub. Although Dickman (1995) believed the species to be a soil-fossicking insectivore, Hall (1980) regarded *A. swainsonii* as a generalist and an opportunistic feeder. During the winter, nests are excavated in creek banks or just below the soil surface, often under the cover of decaying logs or grass (Dickman 1995). *Antechinus swainsonii* was trapped only in the gully and on the medium slopes and ridge within the open forest communities.

Whilst *A. minimus* is listed as rare in Victoria because it is found only in small isolated populations which are thus vulnerable to threats such as wildfire and feral predators (Menkhorst 1995), recent studies have shown populations along the Otway coast (Westbrooke *et al.* 1995) and Port Campbell National Park (Twyford 1997). Whilst there are only two previous records of *S. leucopus* from the Cape Otway area, this may be the result of low capture rates for this species rather than rarity. Its conservation status nonetheless remains unclear (Menkhorst 1995).

Pseudomys fumeus is uncommon or rare throughout its Victorian range (Menkhorst 1995), and was described by Brazenor (1934) from two specimens taken at Olangolah near Beech Forest in the Otway Ranges of south-western Victoria. Another specimen was collected in the same area in 1937. One specimen was trapped at the mouth of Parker River in 1980 and two were captured at Blanket Bay to the east in 1985. Cockburn (1981) suggested that the habitat preferences of *P. fumeus* reflected selection for those areas providing a year-round source of high quality food, rich in nitrogen and, further, suggested that post-fire succession producing an understorey rich in peas and wattles is essential for its continued survival. In this study the two specimens were trapped in low open-forest vegetation, a trapping rate of approximately one per 500 trap nights for this community. Low trapping rates are common for this species and a number of reasons for this have been suggested. Menkhorst and Seebeck (1981) noted that population densities of *P. fumeus* were generally low, possibly due to its preference for drier hillsides with a heath understorey. Even at such sites the species may never develop high population densities. *Pseudomys fumeus* is considered to require careful monitoring, principally because of successional changes in vegetation communities and therefore change in habitat suitability to the species (Menkhorst 1995).

Rattus rattus was introduced to Australia from Europe. It is generally considered to be a vagrant in undisturbed Australian vegetation and is more usually associated with disturbed situations in coastal Australia. Settlement on Parker Hill and camping at Parker River Inlet may have provided the required disturbance for the small population of *R. rattus* that occurred there. A

large percentage of the captures were on the periphery of the flat grassland used by campers and grazed by livestock. These habitats of dense Buffalo Grass, heath or tussock grass may have provided suitable nest sites. *Rattus rattus* has not been captured at Parker River Inlet after 1986. Factors that may have influenced this are:

(i) reduced use of the inlet for camping since the establishment of the National Park and the closure of the inlet access track to vehicles;

(ii) continued euthanasia of specimens trapped on a regular basis from what may have been a population not well established.

Other species recorded in this study are unremarkable in themselves but the very high species richness of mammals, 25 native and three exotic, within an area of 200 ha, makes the area highly significant. Four further native species, *Cercartetus nanus, Potorous tridactylus, Dasyurus maculatus* and *Miniopterus schreibersii* have been recorded within 2 km of the inlet.

Management implications

This study at Parker River Inlet has demonstrated the association of different mammal species with particular vegetation types. Consequently, concern is expressed for the management of the area.

Clearing of woodland for grazing has occurred from Point Franklin to Cape Otway. Pastures are unimproved and were used for grazing cattle, which wandered freely over large areas of pasture, woodland and dune. These cattle have altered the vegetation of the cliffs by trampling, initiating and aggravating erosion, and facilitating the spread of exotic weeds such as *Stenotaphrum secundatum* and *Lagurus ovatus*. Despite being established as a National Park in July 1981, cattle were not excluded until the purchase of a block of private land to the west of the inlet, in 1985. At the inlet of Parker River, livestock had reduced areas of the coastal heath and tussock grasslands to lawns of exotic grass species. These open spaces on level ground and close to the sea attracted many campers. Native plant species such as *Spinifex hirsutus* are susceptible to damage by trampling. *Spinifex hirsutus*, spreading by rhizomes, quickly colonises recent sand accretions to the dunes. However, the rhizomes are broken easily under the loose sand when trampled, and many areas have become devoid of this valuable stabilizing species (Anon 1981). The stability of coastal dunes in southern Australia has been maintained by hand-planting of the vegetatively propagated *Ammophila arenaria*, introduced to Australia from Western Europe and this is well established. Cattle selectively graze the native *S. hirsutus* in preference to the exotic *A. arenaria* (pers. obs.). A number of other exotic species occur in the disturbed communities of the inlet and at least two have become established within the period of this study, i.e. Cape Gooseberry *Physalis peruviana* and Sea Spurge *Euphorbia paralias*.

The preferred habitat of *P. fumeus*, ridge-top sclerophyll forest with a diverse understorey of heath dominated by legumes (Menkhorst and Seebeck 1981), is regenerated by fire and Cockburn (1995) suggests that it is dependent upon post-fire succession for its continued survival. He also considered the species to be in danger of extinction. This study has confirmed the presence of *P. fumeus* within the Otway National Park and appropriate management procedures should be considered along with the needs of other small mammal species.

A notable absentee from the area is the Broad-toothed Rat *Mastacomys fuscus*. According to Menkhorst (1995), the species has been found in dense *Poa* grassland beside Parker River and on dunes within 50 m of the sea. No specimens were recorded at Parker River Inlet despite trapping between 1985 and 1989 in locations where it might be expected.

Mus musculus becomes abundant and ubiquitous about 18 months after a bushfire, at a time when native species of rodent have become rare. The outbreak can last up to 3-4 years, with *M. musculus* disappearing as populations of native rodents begin increasing again (Newsome 1995). A controlled burn was carried out in open forest at Blanket Bay, 4 km east of this study site in January 1990. This has provided the opportunity to assess changes in the small mammal populations following

fire at a site similar to parts of the trapping grid used for this study (Westbrooke and Prevett 2000).

It is apparent that major disturbances through the activity of man or roaming livestock are detrimental to both the plant and animal communities at Parker River Inlet. Such degradation of habitats may favour the exotic mammal species *R. rattus* and *M. musculus* (Watts 1995; Newsome 1995).

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Habitat of the Endangered *Hibbertia procumbens* (Labill.) DC (Dilleniaceae) from the Central Coast of New South Wales

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Abstract

Hibbertia procumbens (Labill.) DC (Dilleniaceae) is currently listed as an endangered species under the *NSW Threatened Species Conservation Act* 1995. This species is extremely rare in New South Wales, with only two records now known for the whole of the State; it is more common in Victoria, where populations are concentrated in the coastal districts, and in Tasmania. Future taxonomic revision may possibly differentiate the New South Wales specimens from those in the more southern States. A new population of *Hibbertia procumbens* is described here for Bumble Hill on the Central Coast of New South Wales. Habitat details are provided for this and the only other known New South Wales location at Strickland State Forest. A conservation risk code for the New South Wales populations is suggested, following the system of Briggs and Leigh (1996). Additional searches for *Hibbertia procumbens* in New South Wales should be made within appropriate habitat both in and outside conservation reserves in the northern Sydney Basin region, to ascertain the conservation status of the species and to assist taxonomic revision. (*The Victorian Naturalist* **119** (2), 2002, 69-74)

Introduction

Hibbertia procumbens (Labill.) DC (Dilleniaceae) is a very rare, summer-flowering, prostrate shrub growing in scrubby heath on sandy soils in New South Wales, Victoria (Harden and Everett 1990), and Tasmania (H Toelken, pers. comm.). Currently, *H. procumbens* is listed as endangered in Schedule 1 of the *NSW Threatened Species Conservation Act* 1995, although nationally it is not considered rare (Briggs and Leigh 1996). In New South Wales, Harden and Everett (1990) note that this species has been recorded only from the Mangrove Mountain area of the Central Coast botanical subdivision. In Victoria, *H. procumbens* is locally common in coastal heathland and heathy woodland, with a discontinuous distribution from the Portland area, Otway Ranges, Anglesea, Western Port (including French and Phillip Islands), Cape Paterson, Wilsons Promontory, near Traralgon and at a few sites east of Orbost (N Walsh, pers. comm.). The species is also reported to be locally common in Tasmania (H Toelken, pers. comm.).

There is some taxonomic uncertainty regarding the correct placement of the New South Wales specimens within this group. The disjunct occurrence in New South Wales of what is currently described as *H. procumbens* from populations in Victoria and Tasmania may suggest that a different taxon is involved. In any case, the New South Wales specimens are recognised as problematic, and will require taxonomic resolution in the future (H Toelken, pers. comm.). Under current legislation in New South Wales, *H. procumbens* is considered endangered, in recognition of the paucity of records and its apparently highly restricted range.

This paper reports on a new population of *H. procumbens* located during vegetation surveys undertaken in Wyong Shire on the Central Coast of New South Wales (Bell in prog.). The site near Bumble Hill on the edge of the Somersby Plateau was recognised as being highly significant for the State, and the opportunity is taken here to document the habitat attributes in this area. The only other known population in New South Wales was also re-visited in order to compare and describe the habitat there.

Previously known records in New South Wales

Previously, *H. procumbens* was known from only one collection in New South Wales, made in Strickland State Forest at Mangrove Mountain near Gosford in October 1991 (P Hind, pers. comm.). This is despite the relatively extensive vegetation survey work that has been carried out in the Sydney region over recent decades. Although present within this State Forest, there is currently no known representation

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of this species within formal conservation reserves. The existing site in Strickland State Forest is approximately 15 km south-east of the new location at Bumble Hill.

Hibbertia procumbens was also collected in December 1998 during searches for the endangered herb *Prostanthera junonis* on behalf of the NSW National Parks and Wildlife Service (S Douglas, pers. comm.). Identification was not possible at this time due to a lack of fertile material, and a cutting was propagated to provide flowering material for later identification. It was only while assessing the status of threatened flora in the Gosford City Council area that the identity of the unknown *H.* was confirmed (Douglas and Burcher in prep.). This was verified in August 2001 when fertile specimens were observed in the field.

Habitat at Bumble Hill

The Bumble Hill record was made in November 2000, within a *Banksia ericifolia* var. *ericifolia-Angophora hispida* scrub/heath on skeletal sandy soils derived from Triassic Hawkesbury sandstone (see Appendix 1 for common names and authorities of all plant species discussed in the text). Soils have been mapped at this location as part of the Lambert (la) soil landscape, which consists of a loose, stony, brown, sandy-loam topsoil with apedal, single-grained structure and a porous sandy fabric, over a yellowish-brown clayey-sand subsoil with apedal massive-to-weakly pedal structure, and a porous earthy fabric (Murphy 1993). The site is located on a mid-to-upper exposed slope (aspect 355°), on a gently sloping sandstone bench (8°), and at an elevation of 90 m ASL. Structurally, the vegetation is composed of a tall shrub layer 2-3 m in height and 20-40% cover, dominated by *Angophora hispida, Banksia ericifolia* var. *ericifolia* and *Leptospermum trinervium*. Below this at a cover of 50-60% is a 1 m layer of shrubs dominated by *Banksia ericifolia* var. *ericifolia, Hakea teretifolia* and *Banksia oblongifolia*. Ground layer vegetation merges with the shrub layer, and is dominated by *Lepyrodia scariosa, Ptilothrix deusta* and *Actinotus minor*. The site appeared to have been burnt approximately 3-5 years prior to survey. Initially, a population of around a dozen plants was estimated for this site, but subsequent searches for the species in adjacent areas during October 2001 revealed a much larger population of between 100-150 plants.

Other associated species within the scrub/heath included (in decreasing order of relative abundance) the shrubs *Pultenaea ferruginea* var. *ferruginea, Petrophile pulchella, Baeckea diosmifolia, Acacia linifolia, Phyllota phylicoides, Bossiaea heterophylla, Lambertia formosa, Hibbertia aspera, Platysace linearifolia, Hakea dactyloides, Acacia* sp. B, *Grevillea buxifolia* subsp. *buxifolia, Acacia suaveolens, Epacris pulchella, Leucopogon esquamatus, Dillwynia sericea* and *Bossiaea scolopendria*; the herbs *Mitrasacme polymorpha, Patersonia sericea, Stackhousia nuda, Dampiera stricta, Phyllanthus hirtellus, H. riparia* and *Scaevola ramosissima*; and the graminoids *Anisopogon avenaceus, Cyathochaeta diandra, Xanthorrhoea resinifera, Lomandra obliqua, Schoenus lepidosperma* subsp. *pachylepis, Xyris complanata, Aristida vagans* and *Lomandra glauca*. The small fern *Lindsaea linearis* and the terrestrial orchid *Cryptostylis erecta* were also present.

Habitat at Strickland State Forest

Efforts were made to revisit the location of the Strickland State Forest record in July and August 2001. Notes accompanying the original collection in 1991 included a description of the habitat as '*Banksia ericifolia–Allocasuarina distyla* open scrub, on skeletal sandy soil with rocks'. The site reference co-ordinates provided did not correspond with the description of the area (inaccurate by approximately 5 km), which indicated that the site was 'along track to Banksia Picnic Area, off Dog Trap Road, Strickland State Forest'. Consequently, a search of the general area around the Banksia Picnic Area managed to locate suitable habitat and plants of *H. procumbens*. While detailed counts were not made at this site, it was estimated that a population of perhaps 100-200, possibly up to 300 plants, occurs here. The Strickland State Forest population is probably the larger of the two known New South Wales sites.

Like Bumble Hill, the Strickland State Forest population occurs within a scrub/heath of *Banksia ericifolia* var. *ericifolia* and some *Angophora hispida*, on skeletal sandy soils derived from the Triassic Hawkesbury sandstone series. Murphy (1993) has mapped the soils at this site as forming part of the Sydney Town (st) soil landscape, although the description of both the soils and the vegetation provided by Murphy (1993) suggest that the area in question is in fact a small unmapped occurrence of the Lambert (la) landscape (see above description). As at Bumble Hill, the site occurs on a gentle upper slope (7°) but at an aspect of 164° and an elevation of 180 m ASL. Structurally, the vegetation consists of a tall shrub layer (4-5 m, 10 % cover) of stunted *Eucalyptus haemastoma* and *Banksia ericifolia* var. *ericifolia*, with some *Leptospermum trinervium* and *Angophora hispida* also apparent. Below this, a combined shrub/ground layer up to 2 m in height and 50-80 % cover occurs, dominated by *Grevillea speciosa, Dillwynia sericea* and *Banksia ericifolia* var. *ericifolia*.

Other species present in the area included (in decreasing order of relative abundance) the shrubs *Banksia oblongifolia, Persoonia isophylla, Leucopogon esquamatus, Bossiaea scolopendria, Bauera microphylla, Hibbertia cistiflora* subsp. *cistiflora, Hakea teretifolia, Epacris pulchella, Pultenaea elliptica, Baeckea diosmifolia, Hakea dactyloides, Acacia suaveolens, Platysace linearifolia, Petrophile pulchella, Persoonia lanceolata, Leptospermum polygalifolium* subsp. *polygalifolium, Grevillea buxifolia* subsp. *buxifolia, Philotheca buxifolia* subsp. *obovata, Hibbertia empetrifolia* subsp. *uncinata*; the herbs *Actinotus minor, Xanthosia tridentata, Drosera auriculata, Gompholobium glabratum*; the graminoids *Leptocarpus tenax, Lepyrodia scariosa, Ptilothrix deusta, Xyris complanata, Patersonia sericea, Lepidosperma filiforme, Xanthorrhoea resinifera, Cyathochaeta diandra, Schoenus lepidosperma* subsp. *pachylepis*; and the ferns/allies *Selaginella uliginosa, Schizaea bifida* and *Lindsaea linearis*. *Allocasuarina distyla* was not observed, although *Allocasuarina littoralis* was in the general area.

Conservation and Management

Populations of *H. procumbens* at both Bumble Hill and Strickland State Forest represent the only known records for New South Wales. Both populations occur on the edge of the Somersby Plateau, an undulating plateau of Triassic Hawkesbury sandstone forming a northerly extension of the Hornsby Plateau (Murphy 1993). Neither site occurs within formal conservation reserves, although use of that part of Strickland State Forest for timber production is unlikely. Within New South Wales, both the northern and southern limits of distribution are represented by these two sites, covering a geographical range of only 15 km. This area is also known for other taxa of interest in the *H.* genus (e.g. *Hibbertia empetrifolia* subsp. *uncinata*), including some as yet undescribed species, which require further investigation (H Toelken, pers. comm.).

In the context of regional vegetation communities in which this species is found, the descriptions of habitat for the two locations fit closely with the Hawkesbury Coastal Banksia Woodland of NPWS (2000). This vegetation type is sporadically distributed around the NSW Central Coast on Hawkesbury sandstone derived soils (particularly the Lambert soil landscape), and hence there is considerable potential for other populations of *H. procumbens* to occur in the region. NPWS (2000) have mapped 5732 ha (extant) of this vegetation type in the Central Coast area. Much of this already occurs within conservation reserves managed by the NSW National Parks and Wildlife Service, including Brisbane Water, Dharug, Popran and Yengo National Parks, and Parr State Recreation Area. Consequently, potential habitat for the species does not appear to be immediately threatened. Several State Forests managed by State Forests of New South Wales also contain this habitat (e.g. Strickland State Forest and Ourimbah State Forest).

Although listed on Schedule 1 of the NSW *Threatened Species Conservation Act*, *H. procumbens* does not have an official conservation risk code under the Briggs and Leigh (1996) system, most likely due to the extent of populations in Victoria and Tasmania. Given the distance

between the New South Wales and more southern populations, further taxonomic revision of this group will probably ultimately recognise two distinct taxa. Consequently, it is suggested that (at least for New South Wales) this species be given a code of 3E, indicating an endangered species with a known geographical range of greater than 100 km, but with no known representation within formal conservation reserves. Should taxonomic revision determine that the New South Wales specimens are in fact distinct from those in the southern States, then a risk code of 2E would be more appropriate. For New South Wales, a regional code of 57 (Central Coast botanical subdivision) should also be included.

The floristic composition of *H. procumbens* habitat on the Central Coast of New South Wales is heavily influenced by fire, particularly in relation to fire frequency and intensity (Bradstock *et al.* 1997). Management strategies for habitat known to support *H. procumbens* are therefore likely to revolve around appropriate fire regimes, although specific research is required to confirm this. The fire response mechanism for other *Hibbertia* species in the Sydney region predominantly involves resprouting from basal shoots, although high intensity fire has been reported to kill some species (Benson and McDougall 1995). Observations made in the field suggest that *H. procumbens* would resprout following fire, since specimens growing on trail margins in Strickland State Forest were noted to have resprouted from basal shoots following trailbike disturbance.

Weed invasion is a concern for the Strickland State Forest population. Surrounding habitat is being invaded by the exotic *Pinus radiata* while trail margins are also affected by invasion of exotic Whisky Grass *Andropogon virginicus*. Appropriate management of the powerline access trail along which several specimens occur is paramount. Erosion, sedimentation and the introduction of non-indigenous fill such as basaltic road-base are currently undermining the integrity of the general habitat, and promoting weed invasion. At Bumble Hill, similar threats are not yet apparent, although the site is on private land in close proximity to a main road.

Future survey of heath and scrub vegetation on Hawkesbury sandstone geology within this part of the Sydney region should include diligent searches for *H. procumbens*, particularly on and around the Somersby Plateau. It would also be desirable for dedicated searches to be made within appropriate habitat in existing conservation reserves in the region to ensure that long term conservation of the species is secured. Further collection of specimens and lodgement at national herbaria is also required to assist in taxonomic revisions of this taxon.

Acknowledgments

Wyong Shire Council is acknowledged for funding the Shire-wide vegetation survey in 2000-2001, during which the Bumble Hill population was discovered. Assistance in the field was ably provided by Jedda Lemmon, while confirmation of *Hibbertia procumbens* specimens from Bumble Hill and Strickland State Forest was undertaken by staff at the National Herbarium of NSW. Neville Walsh (National Herbarium of Victoria) kindly provided location details and general information for Victorian populations, while Hellmut Toelken (State Herbarium of South Australia) provided comments on taxonomy and distribution of this difficult taxon. Peter Hind (National Herbarium of New South Wales) provided information on NSW collections. Travis Peake commented on the manuscript and encouraged further searching for the Strickland State Forest population. Steve Douglas also commented on the manuscript and provided useful information on the Strickland State Forest population.

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Appendix 1. Scientific and common names of species mentioned in text. Nomenclature generally follows Harden (1990-1993) and Harden and Murray (2000), except where recent revisions have been published.

Family	Species and Authority	Common Name
Class Lycopsida (Clubmosses and quillworts)		
Selaginellaceae	*Selaginella uliginosa* (Labill.) Spring	-
Class Filicopsida (Ferns)		
Schizaeaceae	*Schizaea bifida* Willd.	Forked Comb Fern
Lindsaeaceae	*Lindsaea linearis* Sw.	Screw Fern
Class Coniferopsida (Conifers)		
Pinaceae	*Pinus radiata* D.Don *	Radiata Pine
Class Magnoliopsida (Flowering Plants)		
Subclass Magnoliidae (Dicotyledons)		
Dilleniaceae	*Hibbertia procumbens* (Labill.) DC	-
	Hibbertia cistiflora Wakef. Subsp. *cistiflora*	-
	Hibbertia aspera DC	-
	Hibbertia empetrifolia (DC) Hoogland subsp. *uncinata* Toelken	-
	Hibbertia riparia (R.Br. ex DC) Hoogland	-
Euphorbiaceae	*Phyllanthus hirtellus* F. Muell ex Muell. Arg.	Thyme Spurge
Droseraceae	*Drosera auriculata* Backh. ex Planchon	-
Casuarinaceae	*Allocasuarina distyla* (Vent.) L.Johnson	-
	Allocasuarina littoralis (Salisb.) L.Johnson	Black She-oak
Baueraceae	*Bauera microphylla* Sieber ex DC.	-
Proteaceae	*Persoonia lanceolata* Andrews	-
	Persoonia isophylla L.Johnson and P.Weston	-
	Petrophile pulchella (Schrader) R.Br.	-
	Grevillea buxifolia (Smith) R.Br. subsp. *buxifolia*	Grey Spider Flower
	Grevillea speciosa (Knight) Mc Gillivray	Red Spider Flower
	Hakea teretifolia (Salisb.) Britten	-
	Hakea dactyloides (Gaertner) Cav.	-
	Lambertia formosa Smith	Mountain Devil
	Banksia oblongifolia Cav.	-
	Banksia ericifolia L. f. var. *ericifolia*	-
Myrtaceae	*Angophora hispida* (Smith) Blaxell	Dwarf Apple
	Eucalyptus haemastoma Smith	Broad-leaved Scribbly Gum
	Leptospermum trinervium (Smith) J. Thompson	-
	Leptospermum polygalifolium Salisb. subsp. *polygalifolium*	-
	Baeckea diosmifolia Rudge	-
Rutaceae	*Philotheca buxifolia* subsp. *obovata* (G.Don.) Paul G. Wilson	-
Fabaceae: Mimosoideae	*Acacia linifolia* (Vent.) Willd.	Flax-leaved Wattle
	Acacia suaveolens (Smith) Willd.	Sweet Wattle
	Acacia sp. B (Kulnura form of *A. terminalis*)[1]	-
Fabaceae: Faboideae	*Gompholobium glabratum* Sieberi ex DC.	Dainty Wedge Pea
	Phyllota phylicoides (Sieber ex DC.) Benth.	Heath Phyllota
	Pultenaea elliptica Smith	-
	Pultenaea ferruginea Rudge var. *ferruginea*	-
	Dillwynia sericea Cunn.	-
	Bossiaea scolopendria (Andrews) Smith	-
	Bossiaea heterophylla Vent	-

Appendix 1. (cont.)

Family	Species and Authority	Common Name
Epacridaceae	*Epacris pulchella* Cav.	-
	Leucopogon esquamatus R.Br.	-
Goodeniaceae	*Dampiera stricta* (Smith) R.Br.	-
	Scaevola ramosissima (Smith) K.Krause	-
Lamiaceae	*Prostanthera junonis* B.J.Conn	Somersby Mintbush
Apiaceae	*Actinotus minor* (Smith) DC	Lesser Flannel Flower
	Xanthosia tridentata DC	-
	Platysace linearifolia (Cav.) Norman	-
Loganiaceae	*Mitrasacme polymorpha* R.Br.	-
Stackhousiaceae	*Stackhousia nuda* Lindley	-
Subclass Liliidae (Monocotyledons)		
Lomandraceae	*Lomandra obliqua* (Thunb.) J.F.Macbr.	-
	Lomandra glauca (R.Br.) Ewart	Pale Mat-rush
Xanthorrhoeaceae	*Xanthorrhoea resinifera* (Sol. ex Kite) E.C.Nelson and D.J.Bedford	-
Iridaceae	*Patersonia sericea* R.Br.	-
Orchidaceae	*Cryptostylis erecta* R.Br.	Tartan Tongue Orchid
Xyridaceae	*Xyris complanata* R.Br.	-
Cyperaceae	*Schoenus lepidosperma* (F.Muell.) K.L.Wilson subsp. *pachylepis* (S.T. Blake) K.L.Wilson	-
	Lepidosperma filiforme Labill.	-
	Ptilothrix deusta (R.Br.) K.L.Wilson	-
	Cyathochaeta diandra (R.Br.) Nees	-
Restionaceae	*Lepyrodia scariosa* R.Br.	-
	Leptocarpus tenax (Labill.) R.Br.	-
Poaceae	*Andropogon virginicus* L. *	Whisky Grass
	Aristida vagans Cav.	Three-awn Speargrass
	Anisopogon avenaceus R.Br.	Oat Speargrass

* non-native species

[1] a distinct form of *Acacia terminalis* (Salisb.) J.F. Macbr, recognised in *Flora of Australia* Volume 11a as *Acacia* sp. B (Kodela and Tindale 2001).

Wingan Wilderness

Tucked away about half way along the coastal strip that forms the Croajingalong National Park in East Gippsland, and accessible by way of the West Wingan Road, is a very secluded section of the Park at Wingan Inlet (Fig. 1). In recent years the road in, about 18 km east from Cann River and extending 34 km south from the Princes Highway, has been upgraded so that in normal conditions any standard vehicle can have access. The road is not suitable for caravans, but is quite adequate for trailers. If in doubt, inquiries should be made at the Parks Victoria Office in Cann River. During holiday periods, it is necessary to book camping sites.

This particular area, with well appointed camping sites, is a favorite destination for fishermen, but hikers, bird watchers and botanists will all find much of interest. Lyrebirds and reptiles of various sorts were among some of the more obvious examples of the wildlife. I would like to share three observations.

Near the entrance to the camping area is a stand of the Tall Everlasting *Helichrysum elatum* (front cover), which in Victoria is confined to East Gippsland. It is usually found in damp areas, and often

Fig. 1. Wingan Inlet.

Fig. 2. Lilac Lily *Schelhammera undulata.*

along watercourses, in dry sclerophyll forests. The dominant tree in this particular location is Red Bloodwood *Corymbia gummifera* (formerly *Eucalyptus gummifera*) at its southern limit.

Tall Everlasting is a spectacular plant when flowering, usually during the Spring. Up to two metres high, the rather woolly stems support large heads of flowers surrounded by shining white bracts.

Usually tucked away in moist shady spots beneath the understorey, but very visible because of its distinctive coloration, is the Lilac Lily *Schelhammera undulata* (Fig. 2). This is the sole representative of the genus in Victoria and is confined in this State to near Orbost and to far East Gippsland. All of the many specimens seen around Wingan Inlet were procumbent, the flower parts making a strong contrast with the dark green foliage.

Of about 140 species of *Stylidium* found in Australia, ten occur in Victoria. Many of these are small herbs, most with flowering stalks less than 30 cm long. Generally the more spectacular members of the genus are

Fig. 3. Tree Trigger-plant *Stylidium laricifolium.*

found in Western Australia, but the Tree Trigger-plant *Stylidium laricifolium* (Fig. 3), confined in Victoria to the Wingan Inlet area, with stalks up to 150 cm crowned with a panicle of usually white flowers, is as noteworthy as any of them. The foliage is crowded along the stem, the young plants in particular appearing very much like conifer seedlings and this indicates the origin of the specific name, which is derived from the Latin 'larix', meaning 'larch', a European conifer.

These are but three of the many attractions of river, bush, lake and beach at Wingan Inlet.

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The Changing Mountains

When all else is change, mountains seem so solid. However, we should expect mountains to change; change was after all what formed them. I recall one geomorphologist questioning a land manager's assertion that one aim of management was to halt erosion in the mountains – erosion, he pointed out, is a natural process, one that is important in building mountains in the first place. These changes take place over many millennia. However, we are less prepared for changes that occur within our own lifetimes. My thoughts turned to this topic of change as I celebrated 25 years of naturalising in the Snowy Mountains in early March this year with a walk into Blue Lake to copy that first exposure to the mountains with Will Osborne in 1977. On that occasion I saw a Peregrine Falcon and Black-shouldered Kites (neither commonly seen since at that altitude – I guess I was just lucky) and though ticking off ravens, I hardly noticed the pipits. Now I mentally tick off these birds, eyes open for the occasional patrolling kestrel or introduced skylark displaying and ears open for the hidden Australian Raven tucked away amongst the hundreds of Little Ravens, Flame Robins in season (spring) and Pacific Black Ducks in summer and low down near the treeline, White-browed Scrubwrens are all searched for and ticked. These are species that were always here but my laboriously gained expertise now leads me to expect them. But what of the things that weren't there? Brumbies have become a major feature of the alpine zone in just a few years; certainly when I completed field studies for my PhD the pad up to the South Ramshead was walkers only (with the occasional fox), now it is a major horse trail from Dead Horse Gap. Yarrow or Milfoil has spread across the mountains wherever disturbed ground has given it a toehold, and pigs are now commonly found higher than ever before.

Weather always changes from what you remember (even if it doesn't really). One local recalled the oft-repeated 'summers aren't as hot as they used to be. When we were kids we would be swimming all the time.' The difference is that now we are a bit more selective about the temperature needed before we would go for a swim. In the same way snow was always deeper as a kid (but then again our legs were shorter!). Leaving aside faulty memories, there have been documented changes in the climate (covered in the book *Snow: a Natural History; an Uncertain Future*) and some memories... I do recall in the 1970s people ice skating on Sponars Lake; now I haven't seen that for a time! Other changes, possibly associated with climate warming, have been the loss of frogs; the decline of Baw Baw Frogs in Victoria and Alpine Tree Frogs both there and here in the Snowies. We have just completed the annual population monitoring of Southern and Northern Corroboree Frogs; the Southern has declined alarmingly and may have little future except in captive breeding at the Amphibian Research Centre in Victoria (along with the one remaining Spotted Tree Frog from north of the border). So far, the Northern Corroboree Frog is a bit better off.

Is this change all doom and gloom? There are some positives, the change from the broadscale fuel reduction burning in the mountains and the regeneration of the Snow Gums that used to scar the side of the Grey Mare. Following intensive winter fox baiting to protect the Mountain Pygmy Possum there has been a sighting of a Spot-tailed Quoll in the winter snow and the finding of a quoll latrine high above the treeline near Thredbo, reminding me that Richard Helms in 1896 recorded traces of quolls as being abundant in the vicinity of Bogong Moth aestivation sites. Another positive change has been the added interest in the mountains. When I began my naturalising there was very little support for mountain research and very little interest. The number of researchers involved with the Australian Institute of Alpine Studies and the numbers that turned up at the Biodiversity Blitz (see last edition) are heartening evidence of a renewed interest.

It is tempting on an anniversary to reflect on these long-term changes that have taken place, but always of interest are the changes on a smaller scale; these are the ones I love to observe, particularly in this season. Autumn is possibly the time of greatest change – leading to that fundamental difference between summer and winter: the presence of snow. It is the period when animals like the Mountain Pygmy Possum have to put on the weight necessary to get them through to spring (and they are often into hibernation well before the first snow comes). Other animals are shuffling their lives about. Bush Rats deepen their burrows to push them into warmer depths for winter. Despite the well known post-breeding die-off of the male Antechinus it is the autumn that is the most challenging for most Antechinuses at higher elevations with heavier animals losing weight through the autumn, and lighter animals exiting the population. Insects have to lay their eggs before the summer runs out (this is helped in the Alpine Thermocolour Grasshopper by daily changes in body colour to make the best use of the available heat energy of the sun) while those insects that are to overwinter must start to synthesise cryoprotectants (antifreeze and the like) from sugars. Birds flitting over in twittering flocks are Yellow-faced Honeyeaters, the most conspicuous of the emigrant birds in the mountains. The migration of the Bogong Moths back to their natal sites is a less co-ordinated and spectacular event than their arrival, with numbers seemingly melting away over the weeks. For most reptiles and frogs their winter is going to be similar to the insects, a simple case of fattening up, finding a protected hibernaculum and sitting it out. However, for the Corroboree Frogs, their eggs are sitting awaiting the rains that will enable eggs to hatch and the tadpoles to move from their nests in sphagnum moss into the ponds for the winter.

Plants too are hardening for the winter, recovering resources from above-ground tissue, a fact attested to by the changing colours in the mountain heaths. Seed maturation is completed and cold hardiness increases with decreasing temperature in much the same way as in the insects.

Spring may seem a time of major change but it is not so absolute as autumn. The spring thaw is incomplete, winter snow may persist as snowdrifts into March or April, but in autumn we are awaiting that one day when the change becomes absolute, a summer landscape changing subtly into autumn suddenly becomes a winter landscape.

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One Hundred Years Ago

AMONG THE BIRDS OF WESTERN AUSTRALIA, BY ROBERT HALL

On Emus –
Emus can swim rivers if necessary, so there would be no impediment on that account. A curious incident in the domesticated habits of this bird occurred under the notice of Mr. Price Fletcher, who described it to me in the following terms : —"A little three-year-old child was trailing a small tin horse and cart, when along came an Emu and swallowed all but half the string. The remaining half dangled from its beak for half the day unitl cut sufficiently short to allow it to swallow what had been an irritation for hours. Both child and Emu were considerably astonished. Tame Emus are by no means desirable pets, for strange horses when tied to fences will get terribly frightened by the prying bird, and eventually do damage to property. Emus are said to be a nuisence among the flocks, as young lambs will follow any large quickly moving object and thus get led away by Emus in broad areas. By this means lambs soon lose their "dames" and themselves. In addition the Emu seems to take a delight in chasing both lambs and mothers."

From *The Victorian Naturalist* **XVIII**, p.165, March 1902

Jack Hyett OAM (1915-2001)

Naturalist, teacher, author, family man and friend

When asked to write this tribute to the late Jack Hyett, I went first to his books on my shelves. Out fell a collection of newspaper articles, photographs, poems and tributes from various natural history magazines. Jack had given me the poems many years ago written by other authors but expressing his love for the bush.

Enclosed with the poetry was an article written by the late JA Leach MSc at a time when I was about to launch into a teaching career myself in primary and secondary schools. The last paragraph of the article states 'be happy if your pupils are discovering things you know nothing about, for as Libert Bailey, the eminent nature-study apostle, tells us truly that the best teacher of nature-study is the one whose pupils farthest outrun him.'

Jack was a modest man who made light of his staggering number of achievements. He possessed a well-modulated speaking voice and a slow smile which widened into a huge grin when re-living some of his best bush experiences.

A local newspaper (1959) wrote up the ceremony at a primary school in Blackburn to honour him on the publication of the book *A Bushman's Year*. The article quotes 'a book which he wrote during his school holidays!' Jack mentioned on this day he was rushed by excited youngsters for his autograph and many congratulations on the days leading up to the ceremony – I can imagine the wry chuckle as he said 'I must agree it has only been since they discovered they would be let out of school half an hour early so this function could be held.'

Lucky were the children whom he taught in several primary schools, especially one-teacher rural schools. If I had been fortunate to have had even ONE teacher like Jack during primary school! It was not to be. Jack's arithmetic classes were cheerfully interrupted by students to point out birds in the school ground, tortoises were watched during lessons to observe how they breathed, frogs, lizards and insects brought into class by students were welcome diversions both to students and teacher. Even a rounder game was abandoned completely to collect and study a wattle goat moth found by one of the girls. These and other wonderful stories are described in *A Bushman's Year* (1959), with an introduction by the late Alan Marshall, and *A Bushman's Harvest* (1961). Jack pays tribute to his father 'whose interest in the bush and its creatures inspired mine.' If you are lucky these two books can still be found in some second-hand bookshops.

Jack with his chosen profession of teaching went on to inspire so many children, very much as the late Crosbie Morrison had done with his radio shows and Wildlife magazines. Jack's teaching career never really ended, as many of us were to benefit from his CAE courses on Bird Study in Australia. Also his students at the teachers' college will remember his unique style. I remember one evening class at a Box Hill college when he enthusiastically raced to the board and illustrated the skeletal structure of a gannet's body, explaining how when they hit the water when fishing, sometimes from a great height, their skull structure and bone density protects them from injury. He then proceeded to draw other birds and how they survive in the wild. Every adult in the room had his full attention. As an observer of detail in the natural world he excelled.

He was a member of the Bird Observer's Club of Australia from 1933 and recruited many of us to join the club during his lectures. When Jack led an excursion for the club you could be sure of large crowds and very long convoys. For seven years he was involved in mammal and bird surveys of Wilsons Promontory.

He was Foundation President of the Victorian Ornithological Research Group (VORG). The Ringwood Field Naturalists Club, of which he was a founding member, nominated him for the Australian Natural History Medallion, which he received in 1985. He was awarded the medal of The Order of Australia (1997) for his contribution to conservation and the environment, and Honorary Life membership in May 1999 to the Field Naturalists Club of Victoria.

His achievements and awards in natural history study are widespread and many, and include his legacy of books written on a wide range of natural history topics. His talks given to many Field Naturalists and Bird Observer Clubs are legendary. This tribute barely scratches the surface of his many achievements. A recent photo of Jack appears in *The Vic Nat* **116** (5), 158.

As a teacher he inspired and enthused. His love of poetry, the classics, overseas and interstate travel made for many fascinating discussions, and he was always a loyal and caring friend and a top naturalist.

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A Field Companion to Australian Fungi

by Bruce Fuhrer

Publisher: *Blooming Books, 2001 revised edition, paperback, colour photographs. ISBN 1876473401. RRP $24.95*

The first edition of *A Field Companion to Australian Fungi* appeared in 1985, and has been reprinted in 1993 with some minor changes to names inserted as an errata sheet. Bruce Fuhrer's books are well known to us all for their wonderful photographs. Consequently, this revised edition of the out of print and very popular earlier edition has been anticipated keenly for some time. The demand for books such as this attests to the increasing awareness of fungi and related groups by many members within our community. This increasing awareness of fungi and cryptogams has been fostered and encouraged by the quality of Bruce's works on the subject. These publications have provided an introduction to groups of organisms about which there was formerly little readily available illustrated literature. This heightened interest by an increasing number of people has facilitated community mapping and survey schemes for fungi, such as those conducted during naturalist clubs' surveys and forays and Fungimap.

The obvious major difference between this revised edition and the previous one is that the new edition has a soft cover and *Mycena epipterygia* replaces *M. sanguinolenta* on the front cover photograph. As a result of the new soft-cover format, the book is slightly smaller than that of the hard cover edition, lighter and somewhat pliable so that it rests more comfortably in the hand.

A Field Companion to Australian Fungi: Revised Edition maintains the same format as the previous edition and commences with a short discussion about mycological characters, classification, ecology, names and other aspects such as distribution and edibility as well as a simple, visual key. However, while there is an extension to the 'Acknowledgements' there is sadly, no other change to the introductory text. The arrangement of species included in the book follows that of the major groups presented in the visual key and this arrangement permits a novice to quickly find whether a particular fungus is described. The gilled fungi group has the greatest number of species documented and illustrated with photographs and these represent approximately 32 genera. The species range from the captivating little *Mycena austrororida* to the larger and much more robust *Cortinarius radicatus*. The other groups represented are coral fungi, polypores, puffballs, stinkhorns, spine fungi, leather and shelf fungi, jelly and cup fungi.

The revised edition presents over 150 photographs of the same 138 species of commonly occurring fungi in the previous edition, and these exquisite photographs remain the great strength of this book. It is disappointing that no new photographs and no new taxa have been included in this revised edition. Here was a wonderful opportunity to increase the number and range of species featured and to illustrate the extremes of the range of morphological variation and colour that is found in some of the species such as *Colus hirudinosus* or

Dermocybe cramesina. Photographs displaying the range and change of colours as some species mature, for example, the purple tones of *Cortinarius archeri* that turn brown with age would be a useful adjunct, and reduce the likelihood that species will be confused with others. The images are supplemented with thumbnail sketches in the text of each species, but this information is often too brief and lacking in diagnostic detail to really elucidate and confirm identification.

The revised edition of *A Field Companion to Australian Fungi* is therefore essentially the same as the edition that it replaces, except that the 'errata' published with the 1993 reprint, have been incorporated in the text and the names of a further 17 taxa in the previous edition have also been updated or corrected. These updates include the transfer of some of the *Cortinarius* species into the genus *Dermocybe*, and the use of the genus *Laccocephalum* for the sclerotia-forming polypores; for example, *Polyporus mylittae* is now recognised as *L. mylittae,* as are *P. tumulosus* and *P. sclerotinius,* recognised as *L. tumulosus* and *L. sclerotinius* respectively. Although the new names appear in the 'Index', they have not been cross-referenced to the older names, and the synonymy similarly does not appear within the text for each species.

The incorporation into this new edition of labelled illustrations to outline the principle fungal morphological characters listed in the visual key would have enhanced the utility of the edition. As would the inclusion of terms such as glutinous, habitat, parasite, troop and spore print in the glossary to cover the use of these terms in the text. A further suggestion would be to update the list of suggested reading material as the present list has not been updated to include the more recent important mycological works, such as Bougher and Syme (1998), Grgurinovic (1997), nor the revised edition of Young (1994). While these works are perhaps at the more 'professional' end of the spectrum for some, they are often the only remaining current resources to use that are specific to the Australian mycological flora.

What is so important about books such as this is that many people rely on them to identify fungi in the field by trying to match the fungi with the photographs. It is a wonderful sensation to succeed. Often these books are the sole source of readily accessible information for the Australian mycological flora and they perform a very important role in educating, encouraging and fostering interest in these neglected groups of organisms. In the case of fungi, there is now an increasing understanding that fungi are a vital component of nearly every ecosystem and there is a genuine thirst for knowledge about them. This demand for information needs to be satisfied and here was an opportunity to do so.

A Field Companion to Australian Fungi is one of the first books that I reach for when trying to decipher the mysteries encountered during my rambles through the forests. As an avid consumer of wonderfully illustrated books such as this, I hope that further editions will expand the number of species featured and include more descriptive text so that we can expand our knowledge. Many a time of what would otherwise have been an aimless ramble in the bush has been transformed into a treasure hunt as I have eagerly looked for fungi.The book has opened my eyes, and we are indebted to Bruce Fuhrer for making a new edition available to those who do not already own a copy of the previous edition. My comments 'for more' are a reflection of how beneficial I have found the previous edition and my frustration in not having access to more of these wonderful photographs of an even greater number of species. We rely on the author to take up the challenge and to provide us with the tools to increase our understanding of these vital components of the natural world.

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Alexander Clifford Beauglehole

26 August 1920 – 19 January 2002

Cliff was the youngest of the three sons of Richard and Margaret Beauglehole, dairy and potato farmers at Trewalla, near Portland. Soon after Cliff was born the family moved to a mixed farm at Gorae West where Cliff attended the nearby country school, travelling each day on horseback down a bush track. Through natural curiosity and encouragement from his parents he soon developed a good knowledge of the natural history of his area. By the time he left school he could scientifically name about 60 species of local orchids and had begun sending specimens to WH Nicholls, a leading orchid specialist of the period. During the 1940s he discovered three previously undescribed species. Soon after leaving school he began a systematic botanical survey of the Portland area, listing over 750 species, almost double the number then recorded.

In 1949 Cliff married Hilda Oakley. He was able to buy the farm at Gorae West and subsequently their daughters Valerie and Yvonne were born. From the outset Hilda took a keen interest in, and often helped with, Cliff's projects. Her assistance in running the farm was invaluable in enabling him to give time to his explorations.

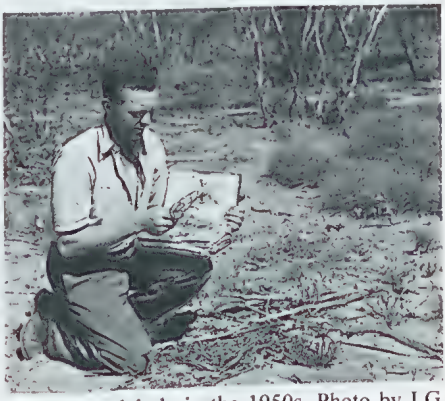
Early in 1950 Cliff began a study and collection of the local native bees, in association with the entomologist Tarlton Rayment[1]. This resulted in the recognition of 30 new species, three of which were named after the collector and five after the district. He also worked on wasps with Tarlton Rayment and on ants with John McAreavy.

Cliff's interest in birds led to the collection and recording of beach washed sea birds from Discovery Bay. Between 1951 and 1963 almost 5000 carcases were collected by Cliff and his helpers including 950 in one day in August 1959. The skeletons were prepared by natural decomposition of the flesh and were eventually donated to museums in Australia and the United States.

During the 1950s Cliff and Fred Davies of Portland commenced an extensive survey of bone deposits in the many limestone caves of the area. Cliff had long been aware of the significance of these and was concerned at the damage being done to the caves through rubbish dumping and road works. In 1963 Cliff and Fred, together with a team of local naturalists, started the excavation of McEachern's Death Trap Cave. Several tons of cave sediments were sieved and the identifiable remains of some 2,000 animals were recovered. In 1964-5 Norman Wakefield[2] became involved in the excavation. The assessment of this material added immensely to the knowledge of the faunal succession of the area.

Throughout these years, Cliff continued his botanical explorations, extending his field to include the non-vascular plants. He covered the whole of the south-west area of Victoria in search of mosses, liverworts, lichens and fungi. He also studied and collected the marine and freshwater algae of his area. He had an amazing ability to recognize new or rare species and his collections are proving a treasure house for present day taxonomists.

During the 1960s Cliff widened his horizons still further and undertook two trips to Lord Howe Island, one long trip through the Northern Territory and West Australia and three shorter trips in central Australia. On each occasion he brought home large collections of specimens. In 1967 he embarked on a full-scale botanical survey



Cliff Beauglehole in the 1950s. Photo by LG Chandler.

of the Grampians. During the 1940s he had made several trips by motor-bike to some of the remoter areas of the Victoria Range and believed that, in spite of a good deal of work done by others, there was still much to be discovered. Cliff was already corresponding with Jim Willis at the National Herbarium and had accompanied him on field trips in the Grampians and Portland area. Jim's encouragement in the Grampians survey also led to the first official recognition of Cliff's work, when he received a grant from the Maud Gibson Gardens Trust.

Following this first survey Cliff worked for the National Parks Service in Western Victoria. He then moved on to a study of East Gippsland and eventually completed plant surveys of the whole of Victoria. This work was subsidised by the Land Conservation Council of Victoria who published his results in the form of conservation recommendations. Cliff subsequently published complete checklists for the whole State. He received some financial support from the Western Victorian Field Naturalists' Clubs Association and from individual clubs and kindred associations. He also received a substantial grant from the Utah Foundation (USA) toward the alpine area surveys, and a grant from Alcoa Australia for work on their smelter site in Portland. He was influential in inspiring many country naturalists to continue to monitor their environment, enabling them to report reliably on conservation issues.

Botanists throughout Australia and many from overseas knew Cliff personally. He willingly gave time to guiding and assisting visitors doing fieldwork in his area. His friends and associates have lasting memories of expeditions with Cliff. His boundless energy and enthusiasm and his wide knowledge of the environment were exhilarating. Lunch breaks provided an opportunity to study marauding insects and to watch birds. His keen eye for different or unusual plants and his meticulous care of his specimens were an inspiration and example to less experienced field workers. Above all he will be remembered for the diversity and quality of his collections, numbering over 90,000, which have been lodged in herbaria all over Australia and overseas. These will continue to be an invaluable resource and a permanent memorial to his dedication.

Taxa named after Cliff.

Vascular Plants
Bassia beaugleholei Ising
Caladenia beaugleholei D.I.Jones
Calonema beaugleholei D.L.Jones
Epilobium brunnescens subsp. *beaugleholei* K.R.West & P.H.Raven
Lobelia beaugleholei D.E.Albrecht
Prasophyllum beaugleholei W.H.Nicholls
Solanum beaugleholei D.E.Symon
Stylidium beaugleholei J.H.Willis
Utricularia beaugleholei R.J.Gassin
Villarsia unbricola var. *beaugleholei* H.I.Aston
Marine alga
Helminthoclada beaugleholei Womersley
Moss
Phascum beaugleholei I.G.Stone
Lichen
Heterodea beaugleholei Filson
Bees
Exoneura cliffordiella Rayment
Hylaeus cliffordiellus Rayment
Megachila cliffordii Rayment

Cliff participated with local naturalists in many campaigns for environmental conservation. Their efforts were rewarded when the Mount Richmond and Lower Glenelg National Parks were gazetted. He was actively involved in the formation of the Western Victorian Conservation Committee that led the battle for the preservation of the Little Desert. He was a foundation member of the Portland Field Naturalists Club and of the Western Victorian Field Naturalists Clubs Association, a member of the National Parks Association and of the Bird Observers Club. In 1982 he became an Honorary Member of the Field Naturalists Club of Victoria in recognition of 40 years continuous membership. In 1971 he was awarded the Australian Natural History Medallion[3] and in 1984 the Medal of the Order of Australia.

Cliff is survived by his wife, two daughters, seven grandchildren and two great-great grandchildren.

[1] Bees of the Portland District (1953), Tarlton Rayment
[2] *The Victorian Naturalist* **84**, 363-83 (1967)
[3] *The Victorian Naturalist* **88**, 344-46 and 360-361 (1971)

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Wildflowers of Sydney and Adjoining Areas

by Alan Fairley

Publisher: *Bloomings Books 2001. 268 photographs, ISBN 187647338X, RRP $32.95*

The blank space on top of the cover of this book should read '**A Field Guide to the** Wildflowers of Sydney and Adjoining Areas'. Perhaps this was a publisher decision and not the author's. This compact, easy-to-use book is just perfect for the rain coat, parka or rucksack pocket.

The alphabetical layout is quick and easy to use in the field, although botanical groupings can be difficult if one is not sure of the family, e.g. a typical page layout is:

Acacia binervata Two-veined Hickory
Family Mimosaceae

This is followed by a coloured photo, description, flowering period, distribution, habitat, notes, similar species and specific sites. In other words all you need to know from a Field Guide.

If I had possessed Alan's book on previous trips to Kuring-gai Chase, Royal National Park and Lane Cove National Park, my plant identification would have been much easier with so many of the commonly seen species all in one book.

On my first trip to the above-mentioned places, I was just learning botany and I remember juggling at least three books, cross-referencing and burning the midnight oil. For this reason I think Alan's book will suit the beginner as well as the more experienced plant lover.

All photographs have been taken by the author, in situ, without flashlight. Most photos are adequate for identification with some outstanding photos of *Telopea speciosissima*, the calistemons, banksias, *Philotheca*, *Correa* and *Thysanotus tuberosus*.

I was disappointed that some of the smaller flowers were not filmed with a close-up lens, i.e. *Rulingia hermanniifolia*, *Micromyrtus ciliata*, *Grevillea buxifolia*, *Hardenbergia violacea* and the baeckias. The author mentions the twisted labellum in *Pterostylis curta* but has photographed the back and side of two specimens. The same with *Pterostylis concinna*, where the deeply notched labellum is mentioned but not shown. *Drosera spathulata* and *Caleana major* could have been sharper and larger. Identification of eucalypt species would have been easier with close-up photos of fruits on **all** species. The small insert photo, showing in some instances canopy or trunk, are not helpful in identification.

The author states that his book *Wildflowers of Sydney* aims to encourage an appreciation of the floral beauty and **variety** of this area, but I was a little disappointed that none of the beautiful grasses in full bloom were included.

Attention to these few minor drawbacks of the book in my view could have improved an already fantastic Field Guide to some of the most beautiful and accessible areas not far from Sydney.

A map of Sydney and adjoining areas is provided and all the places mentioned in the book are shaded green. This works well with site information specified on each page for every plant described.

The references and further reading will be much appreciated by the reader and the glossary is what you would expect from an experienced naturalist, bushwalker and author of 25 books.

This book is not just for the resident or visitor to Sydney it also contains 122 Victorian species and 153 Queensland species which also occur in Sydney and adjoining areas. Only 34 are restricted in their distribution to the Sydney region.

I would highly recommended the purchase of this great, compact little book, bulging with information to anyone planning a trip to Sydney or adjoining areas.

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The Field Naturalists Club of Victoria Inc.

Reg No A0033611X

Established 1880

In which is incorporated the Microscopical Society of Victoria

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Murray River Special Issue Part One

F.N.C.V.

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Introduction – Murray River Special Issue

Terry Hillman*

Australia's major river; a resource critical to our national rural production; a beautiful and sometimes unique landscape; an ecosystem under threat – the Murray is all of these.

The Murray Darling system drains about $^1/_7$ of Australia's surface but, despite its size, flow volumes are small reflecting the arid nature of most of its catchment. The average annual (natural) discharge from the system is equivalent to 16-17 hours' flow from the Amazon. The Basin supports nearly half of Australia's rural production. On average, water use (almost all irrigation) removes around ¾ of the Murray's water before it reaches the sea[1] and dams and weirs drastically change the pattern of flow.

Two other key aspects of the Murray's flow are variability ('droughts and flooding rains') and unpredictability. These conditions favour organisms adapted to periods of wet and dry extremes with little seasonal or inter-annual reliability[2]. Many of the papers in this special issue of *The Victorian Naturalist* deal with organisms or whole systems (e.g. River Red Gums, turtles, and floodplain wetlands) which depend on rainfall or flow cues to initiate vital functions. Again, the effects of flow regulation are significant here.

Beauty is, of course, personal and ascribed by the 'beholder' but 'wetness and dryness' must surely contribute much to what is beautiful in the Murray landscape and the response of its organisms to these forces provides what is characteristic and sometimes unique.

In natural resources it is a common mistake to confuse 'use' with 'management', and most of what we have termed management in the Murray to this point in time has really been the development of more efficient ways of using the resource. Management implies knowledge. If we set out to manage a natural resource we need to know how it works – which means in this case that we need an understanding of the 'Murray ecosystem', its key organisms, its flow-related processes, its biodiversity and the factors supporting it. This special issue provides knowledge at all these levels. Current knowledge regarding fish, terrestrial vertebrates, and invertebrates (aquatic and terrestrial) is provided. The significance of the floodplain as a functional part of the river is recognised through papers on Red Gum forests, their fauna and the significance of fallen timber, and on floodplain wetlands. Geomorphology and connectivity with wetlands are two important flow-related issues discussed. Diversity at every level from fish to microinvertebrates is 'showcased' and includes a useful key to tadpoles and a fascinating introduction into how biodiversity is maintained using the example of niche segregation by turtle species.

This special issue of *The Victorian Naturalist* represents a valuable and accessible compendium of knowledge about the Murray. For those who remember the Royal Society of Victoria symposium on the Murray Darling held in October 1977 (I do, sadly) it is instructive to see how far we have developed in knowledge and emphasis over the past 25 years. Compendia are usually shelved for future reference as a need arises. These papers should be read now. We are facing important decisions regarding the management of the Murray – particularly flow regulation – and the community (regional and national) will need to form an opinion regarding the trade-off between water for production and water for supporting the Murray ecosystem. This special issue will provide an ecological basis on which such an opinion can (and should) be formed.

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[1] Reducing the output to 4-5 hours of 'Amazon flow'.

[2] Note that the enforced reliability of seasonal flow, resulting from river regulation, tends to remove the competitive advantage which such adaptation would otherwise provide.

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Executive Editor: Merilyn Grey
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This issue is dedicated to
Natalie Joanne Smith (31 May 1974 – 22 July 2002)

Introduction, *by Terry Hillman* 86

National Parks and Reserves on the Murray River: an Historical Perspective, *by Daniel Catrice* 88

Geomorphology of the Murray River Basin, *by Noel Schleiger* 95

Floodplain Wetlands: the Jewels of the Murray River, *by Rhonda Butcher and Michael Reid* 102

Habitat Change in River Red Gum Floodplains: Depletion of Fallen Timber and Impacts on Biodiversity, *by Ralph Mac Nally, Andrea Ballinger and Gregory Horrocks* 107

Vertebrate Fauna of Barmah Forest, a Large Forest of River Red Gum *Eucalyptus camaldulensis* on the Floodplain of the Murray River, *by Richard H Loyn, Linda F Lumsden and Keith A Ward* 114

The Distribution and Conservation Status of the Reptile Fauna of the Murray River Region in Victoria, *by Geoff Brown* 133

Tadpoles of South-eastern Australia: a Guide with Keys, *by Marion Anstis, reviewed by Angus Martin* 144

Rivers as Ecological Systems: The Murray-Darling Basin, *edited by WJ Young, reviewed by Gerry Quinn* 147

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Cover: Morning reflections on a Murray River billabong near Mildura. Photo by Anne Morton.

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National Parks and Reserves on the Murray River: an Historical Perspective

Daniel Catrice[1]

Abstract

Attempts to establish national parks and reserves along the Murray River occurred late in the history of Victoria's conservation movement. For much of its recent history the Murray has been made to serve industry and agriculture. The first timber reserves and State forests, which had been set aside from 1869, confirmed a pattern of exploitation which went largely unquestioned until well into the twentieth century. This article looks at settlement and land-use along the Murray and the efforts of conservation groups to protect the lands bordering the river from unregulated development. It concludes with a brief historical overview of the key parks and reserves along the river – Hattah-Kulkyne, Murray-Sunset and Alpine National Parks; Barmah State Park; and Murray Kulkyne Park.
(*The Victorian Naturalist* **119** (3), 2002, 88-94)

Introduction

The Murray River is the main stream of Australia's greatest and most important river system. It rises in the Australian Alps just below Mt Kosciuszko and enters the sea in South Australia. For 1800 km of its length it forms the border between New South Wales and Victoria. This journey takes the river through some of Victoria's most significant and diverse natural landscapes, from wild forested gorges, through riverine plains and majestic Red Gum forests, to semi-arid desert country.

Sadly, the river has been taken for granted for most of its recent history. By the 1840s most of the river frontage had been taken up by land-hungry squatters for whom the river was a source of water and, later, a convenient transport route for produce and supplies. The floodplain forests were exploited as a timber resource and the country beyond was partitioned into farms and grazing runs. To promote agricultural settlement the river was dammed and its waters diverted for irrigation projects. The Murray is now a regulated river. Weirs and dams have ensured water in the Murray all year round, but these have turned the river into a series of connected pools.

The conservation movement turned its attention to the Murray relatively late. The first national park along the river, Hattah Lakes, was reserved only in 1960, and today there are still only a scattering of conservation reserves. Groups like the Field Naturalists Club of Victoria and the Royal Australasian Ornithologists Union began to show interest in the Murray from the early 1900s, and with the assistance of sympathetic officers in the Fisheries and Wildlife Department and the Forests Branch of the Lands Department, important areas like the Kulkyne and Barmah forests were managed with greater care.

This growing enthusiasm for nature emerged from a sense that too much had been lost in the years since white settlement. As one writer observed: 'Nature, as if offended, withdraws half her beauty from the land; the pasture gradually loses its freshness, some of the lakes and rivers run low, others become wholly dry. The wild animals, the former peaceful denizens of the soil, are not more to be found, and the explorer, who has gazed on the district in its first luxuriance, has seen it as it never can be seen again' (Henry W Haygarth 1848, cited in Dingle 1984: 138).

Over time, conservation groups became more vocal in their demands for the establishment of national parks to preserve areas of 'unspoilt nature'. This article investigates some of the human impacts of settlement and land-use along the Murray and reviews the various efforts to protect land and resources in the face of the rapid, sometimes devastating changes worked upon the landscape since European settlement.

Exploration and settlement

The first Europeans to see the Murray River were the exploration party led by Hamilton Hume and William Hovell. They crossed the river near Albury in 1824, naming it the Hume. Just six years later the explorer Charles Sturt renamed it the Murray in honour of Sir George Murray,

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then British Secretary of State for the Colonies. Always with an eye to the future, Sturt saw the Murray as a river highway helping to open up vast tracts of the Australian outback. After Sturt came Major Thomas Mitchell who crossed the Murray at Robinvale in 1836. Like Sturt, Mitchell believed the river should be made to serve a purpose. Travelling down the river towards Swan Hill he noted 'grassy plains bounded by sand hills on which grew pines' and predicted, accurately, that the area would be favourable for cereal crops, grazing or irrigation (Bardwell 1990: 23).

Explorers like Hume and Hovell and Major Mitchell travelled with an eye for new pasture, so it is not surprising that squatters soon followed in their footsteps. The Murray River promised a near permanent water supply, natural pasture and a good supply of timber. Within ten years of Mitchell's expedition, squatters had taken up most of the river frontage.

Edward Curr, a Tasmanian merchant and landowner, established a run at Barmah in 1841. Curr later wrote that the land was flooded for several months of the year, but then 'abounded ... with excellent sheep feed, in the shape of couch grass, young reeds and so on'. It was, he said, 'usually as green as an emerald from November to March when [other] pastures were withered and dried' (Curr 1965: 76).

From the outset, settlers drastically changed the environment. Trampling by stock compacted delicate vegetation and soil, muddied and eroded precious watercourses, and introduced and spread new grasses. Cattle selected the most palatable species, which led to a decline in the density and diversity of native plants. They devoured the fine fuels that carried fire, leading to the invasion of native grasslands by scrub. They spread exotic weeds in fur and dung. They removed seed heads and flowers, which disrupted plant reproduction.

After the squatters came selectors, encouraged by a series of Land Acts which had been enacted in the 1860s. Selectors who took up land were required by the government to 'improve' their selections by clearing vegetation. They did this with indiscriminate zeal, spurred on by the need to render every acre productive. Ringbarking was the cheapest form of clearing as one contributor to *The Victorian Naturalist* found when he visited the country between Kulkyne Station and Mournpall in 1914: 'twenty years previous to our visit these trees [Black Box *Eucalyptus largiflorens*] had been ringed, and the resulting consequences were acres of bare, wind-swept earth, destitute of aught green, and a bewildering interlacement of fallen trunks, and limbs that would appall even an old-time South Gippsland pioneer' (*The Victorian Naturalist* **31**, 1914).

Settlers also made extensive use of River Red Gum *Eucalyptus camaldulensis* for huts and fences, and despite a proclamation that all Murray Pine *Callitris* spp. within ten miles of the river was to be left untouched, by 1875 the local forester at Barmah reported that all of the Murray Pine stands at Barmah Island had been removed (Hibbins 1991).

Land clearing upset the ecological balance. In 1858, the naturalist Gerard Krefft explored the lower Murray and Darling Rivers with Victorian Government Zoologist William Blandowski. Krefft noted that the Rabbit-rat *Conilurus albipes*, Gray's jerboa Kangaroo or Burrowing Bettong *Bettongia lesueur graii* and several other species of marsupial had become rare or extinct on the Victorian side of the Murray (Dingle 1984). Ironically, others complained that the kangaroo and possum were multiplying at an astounding rate, due in part to the decimation of Aboriginal tribes who had hunted them for food.

Some of the earliest settlers looked back in later years and lamented the changes that they saw. Edward Curr decided that 'fences and tree-ringing have not improved the scene' nor could he enthuse over progress when old forests along the Murray were 'fast being converted by steam sawmills into railway sleepers'. He remembered with regret 'the primitive scene, the Black with his fishing canoe, the silence, the gum-trees' (cited in Dingle 1984: 138).

'The Nile of Australia'

Navigation was the first commercial use of the Murray. River boats began operating on the Murray as early as 1853, carrying supplies inland and returning with produce. They opened up remote areas for settlement and helped to make the pastoral

and agricultural industry more profitable. They were also able to carry goods more efficiently than bullock dray. So great was the promise of river transport that some began to talk of the Murray as 'The Nile of Australia' or 'The Mississippi of New Holland' (Davies 1978: 34).

By the 1870s up to thirty steamers and as many barges worked the Murray, Darling and Murrumbidgee Rivers. The bulk of the Riverina woolclip was thus transported southwards through the ports of Echuca and Swan Hill (Priestley 1984: 59). Smaller steamers worked the 'top end' ports of Tocumwal and Albury. Over the next thirty years the railways slowly robbed the river trade of the bulk of its traffic. By the mid-1930s it had virtually ceased.

To meet the river boats' need for fuel, vast quantities of Buloke *Casuarina luehmannii*, River Red Gum and Black Box were cut. Early steamers consumed wood at the rate of about one ton every eight hours; later, more powerful steamers had a wood consumption of one ton per two hours (Davies 1978: 46). Strenuous efforts were also made to clear the river of 'snags', the fallen trees and limbs which fell into the water. This assisted navigation but had a marked effect on native fish, particularly Murray Cod *Maccullochella peeli*, which used fallen trees as shelter and breeding habitat. Fish numbers declined dramatically during this period, from 29,064 kilograms netted in 1835 to only 4273 kilograms taken from the same areas in 1896 (Mackay and Eastburn 1990).

Ronald East of the State Rivers and Water Supply Commission stands astride the Murray River near Nyah State Forest during the drought of 1923. (Picture Collection, State Library of Victoria)

Irrigation

Irrigators began tapping the waters of the Murray in the 1870s. Headworks were constructed to divert water from the Murray near Gunbower Creek and an off-take supplied the Cohuna, Kerang and Koondrook districts. The dry years which began in 1877 saw other growers clutch at the promise of irrigation. They were assisted by the government which assumed control over all the natural water resources in the State in 1886 (Eastburn 1990).

The most audacious irrigation project took shape at Mildura. In 1884 Canadian-born brothers George and Ben Chaffey were invited by the Victorian government to establish an irrigation settlement on the Murray (Davies 1978). The Chaffeys were granted 50,000 acres of rabbit-infested land which they cleared, subdivided and serviced with water channels. Huge pumps were placed in 1889 at Psyche Bend where water was drawn from the Murray and pumped to Kings Billabong. From there, through a series of pumps and open channels it was distributed throughout the area. At Psyche Bend the steam engine drove three centrifugal pumps, each delivering 8000 gallons of water per minute.

Ultimately, irrigation along the Murray was not the success it was envisaged by government or farmers. Environmentally, it was disastrous. The waste of water through evaporation and seepage was enormous. Worse still was the effect of clearing and ploughing on vast areas inland from the river. This allowed rain to run straight into the subsoil raising the water table and bringing saline groundwater close to the soil surface. The introduction of irrigation water exacerbated the problem. Irrigation-

induced salinisation was recorded at Mildura as early as 1895 (Eastburn 1990). By 1911 it appeared near Cohuna and Kerang. Today it affects virtually all regional settings along the river, including the highlands, the riverine plain and the mallee of the Murray-Darling Basin.

Timber reserves and state forests

The first attempts to control land and resources along the Murray came in 1865 when the Victorian government gave itself the power to proclaim reserves for the 'preservation and growth of timber' (Wright 1989: 107). By the close of the decade 276,116 acres had been set aside as state forests and timber reserves, including the Barmah Forest of 19,600 acres, created in 1869 (Wright 1989). Further reserves were created at places like Gunbower Island, Nyah and Walpolla, partly to halt the damage being done to River Red Gum forests as a result of unregulated harvesting, but also to secure a valuable economic resource.

These developments were not motivated by ecological intent. Government action was propelled largely by utilitarian concerns. Red Gum forests along the Murray continued to be heavily exploited for mill logs. During the nineteenth century, sawmillers had only to pay £15 to set up a mill in the forest, and for £10 for cartage and £5 for each man employed in felling timber, he could fell the pick of the trees in the forest (Fahey 1987). In the Barmah Forest the Red Gum trade flourished, prompting one observer to claim that the timber was an 'object of worship on the Murray':

> The mills declare dividends because of it; the sleeper-cutter keeps the pot boiling in return for his daily sweat upon it. The bullock driver draws his Saturday night beer from it. The axeman's camp in the bush is kept supplied in tucker by it. The bargemaster, the deck hand, and the skipper of the river tramp knows its value well (Brady 1912, cited in Hibbins 1991: 38).

The 1901 Royal Commission on State Forests and Timber Reserves reported critically on the use and management of the

A load of Red Gum timber arrives at the Evans Bros sawmill in Echuca, 1923. (Historic Places Section, DNRE)

Barmah Forest. The Commission noted that the forest had been cut over several times, and that at the current rates of cutting, the forest would not yield five years' supply (Fahey 1987).

A similar pattern of use developed in most of the Red Gum forests along the river. By 1932 the district forester at Swan Hill reported that all the red gum at Annuello, Mamboing and Toll Toll had been cut out ('Hattah-Kulkyne National Park' Resource Collection File F/C: 3/1).

It took many decades for the State's forests to be placed under more effective management. Although a series of bills specifically for forest legislation were introduced into parliament, in 1879, 1881, 1887 and 1892, none was enacted. Finally, in 1907 a Forests Act was passed, which provided for the establishment of a State Forests Department under a Minister of Forests. A Conservator of Forests was appointed, with appropriate supporting staff and power to declare permanent forest reserve (Moulds 1991). Over the next decade, several initiatives were undertaken, including improvement works on the forest estate, the establishment of hardwood plantations and improved fire protection measures.

From the 1920s foresters based at Ouyen, Swan Hill, Nyah and Mildura made attempts to re-afforest native pine areas. Unfortunately, until the 1960s these efforts were largely unsuccessful. In the Barmah Forest, thinning and coppice treatment was carried out in the 1920s and 1930s. Foresters also experimented with non-indigenous species. At the Timberoo Forest in the 1930s Red Ironbark *Eucalyptus sideroxylon* and Silky Oak *Grevillea robus-*

ta were trialed ('Hattah-Kulkyne National Park' Resource Collection File).

Foresters were often the first advocates for conservation. It was at their insistence, during the 1930s, that settlers in the Hattah-Kulkyne area were forbidden to remove native pines from their selections. In the Barmah Forest in the 1940s foresters and scientists began to re-assess the impact of grazing. Forester, WP Tingate drew attention to the damage done to saplings by cattle. 'When grass was dry' he said, 'cattle would eat anything green'. Tingate's concerns were echoed by his colleague, Stan Duncan, who observed in 1950 that there was little hope for widespread regeneration of the forest until grazing was discontinued. The Forests Commission acted on this advice and in 1950 Barmah West, Yalca and portions of Yielima were closed to cattle (Fahey 1987).

Water reserves

Another government concern of the 1870s and 1880s was the need to protect water resources from the designs of squatters and selectors. Thus, in 1881 all unalienated land within one to one-and-a-half chains of the colony's 'Rivers, Rivulets, Creeks, Channels, Aqueducts, Lakes, Reservoirs, Swamps, Inlets, Loughs and Straits' was reserved (Wright 1989: 224). The order ensured the Murray River water frontage was retained in public ownership and today this corridor forms the basis of the Murray River Reserves managed by Parks Victoria.

National parks

For many conservation-minded people, the creation of State forests and Crown land reserves was not enough. Towards the end of the nineteenth century a growing body of scientific opinion became increasingly vocal in their demands for the protection of wildlife and the establishment of national parks. In the broader community too there was a growing awareness of the natural world. Changing recreation patterns brought about by extensions to the rail network and the emergence of field naturalist and bushwalking clubs awakened people to the beauties of nature.

The Field Naturalists Club of Victoria (FNCV) was one of the first supporters of national parks. Established in 1880, the FNCV combined the desire for open air recreation with an interest in the natural environment. The Club instituted walking and camping expeditions in which the observation of wildlife and the collection of botanical specimens were important activities. The FNCV was soon joined by other societies, including the Wattle Club, the Royal Australasian Ornithologists Union, and the Bird Observers Club. This small but committed conservation movement, led by influential spokesmen like Baldwin Spencer and Sir James Barrett, began to exert pressure on the government to protect Victoria's bushland.

In 1914, the FNCV became interested in the Hattah Lakes system near Mildura. At its meeting on 14 December the Club decided to write to the Fisheries and Game Department and request that the area be proclaimed a sanctuary for native game. Native game sanctuaries were proclaimed under the *Game Act* of 1890 and made it unlawful for any person to kill any native game within a designated area and specifically mentioned by proclamation (Mahon 1992). Of particular concern to the FNCV was the practice of punt-gun shooting on Lake Mournpall. Speaking for the resolution, JG O'Donoghue reported on a recent visit to the Lake where he claimed that, after a single discharge of the gun used by one individual, as many as 72 pairs of ducks had been 'picked up' (*The Victorian Naturalist* 1915: 31). The resolution was supported by the Inspector of Fisheries and Game, Mr F Lewis, and in 1915 an extensive area embracing parts of Chalka Creek, Lakes Hattah, Little Hattah, Mournpall and Brockie, together with all land within half a mile of the creek and lake, was proclaimed a sanctuary for native game (*The Victorian Naturalist* 1915: 32).

In 1919, about 3620 acres were reserved as the Kulkyne State Forest, and an additional 77,470 acres were dedicated in 1924. A Kulkyne National Park was first proposed in 1938 when Mr LG Chandler of Red Cliffs outlined to the Ornithologist's Union and the FNCV the desirability as a national park of the Kulkyne State Forest and an area of Crown land to the west. A committee of the Union investigated the request and decided that the proposal was premature because of the then unsatisfactory administration of national parks in

Victoria. The Union recommended instead that the area should be added to the State forest and administered as an area for the conservation of mallee fauna and flora. The government agreed to the request and 42,000 acres were added to the State Forest in 1941. At the same time, the whole Kulkyne State Forest was declared a sanctuary for native game ('Hattah-Kulkyne National Park' Resource Collection File).

In 1956, after a long campaign by the FNCV and the Victorian National Parks Association (VNPA), the Victorian government passed Australia's first legislation for the control of national parks. The *National Parks Act* created a National Parks Authority, one of the nation's first statutory bodies to oversee the management of national parks.

While the *Act* provided for the management of national parks, it did not make adequate provision for the selection of new areas which were required in order to give a broad representation of ecosystems within the State. The VNPA recognised that the State's network of national parks was far from being a representative sample of ecosystems. A survey by the Association revealed that a considerable portion of the sixty-two 'vegetational alliances' identified were not protected in existing reserves (Frankenberg 1971). The Kulkyne State Forest included important areas of the 'Saltbush, Bluebush' alliance comprising low shrubland and low open-shrubland. In 1959 the VNPA submitted an extensive report to the government requesting the reservation of the entire forest as a national park (*VNPA Newsletter*, October 1959).

Consequently, in 1960 an area of approximately 18,000 hectares, including Lake Hattah was reserved as Hattah Lakes National Park. In 1980 the surrounding State forest which had previously been held under grazing lease was incorporated to form the Hattah-Kulkyne National Park of 48,000 hectares.

Since 1970 the reservation of new national parks and conservation reserves has been based on recommendations by the Land Conservation Council (LCC), now the Environment Conservation Council. The LCC was created in the aftermath of the Little Desert dispute when, in the face of concerted public opposition, the government abandoned its plans to open up areas of the Little Desert for farming. The dispute led to the reservation of the Little Desert as a national park, but more importantly it convinced the Government that a more systematic system of land-use planning was required to balance the competing claims for uncommitted Crown land. The outcome was the *Land Conservation Act* 1970 which established a Land Conservation Council to make recommendations to the Government on the balanced use of public land in Victoria.

The Little Desert dispute was a watershed in the history of the conservation movement in Victoria. It changed forever the method by which decisions were made about the future use of Crown land. It also revealed the extent of public support for conservation, shaped new attitudes about the environment, and helped the conservation movement to refine its campaign techniques.

By 1978, the Land Conservation Council had completed reports on fourteen investigation areas, although only two of these reports covered areas adjoining the Murray: North East 1 (1973) and Mallee (1977). LCC recommendations led to the reservation of 20 new parks under the *National Parks Act* 1978, increasing the area reserved under the *Act* from 283,000 hectares to 774,000 hectares.

Only one park along the Murray was included under the new legislation. The Murray Kulkyne Park, comprising 1550 hectares of Murray River floodplain, was proclaimed as a result of the 1977 LCC investigation into the Mallee study area. In 1990 the Park was increased in size to 3530 hectares with the addition of the Liparoo Block and renamed Murray Kulkyne Regional Park.

In 1982 Barmah Forest was declared a wetland of international importance under the Ramsar Convention, the international treaty to protect wetlands, and in 1987 the LCC recommendation of 1985 to create the Barmah State Park of 7,900 hectares was finally implemented. The park comprised two sections: the first incorporating wetlands and forests at Top Island, War Plain and Barmah Lakes; the second covering a drier forest of River Red Gum, Grey Box *Eucalyptus microcarpa*, Yellow Box *Eucalyptus melliodora* and Black Box *Eucalyptus largiflorens*.

Two of the largest parks along the Murray River protect vastly different ecosystems. After decades of argument and debate, a series of national parks in the alpine area were reserved by the Victorian government in 1979. These parks, which included the Cobberas-Tingaringy National Park along the headwaters of the Murray, were joined in 1989 as the Alpine National Park. Two years later, Murray Sunset National Park of 633,000 hectares was declared in the semi-arid desert country beyond Mildura. The park is the second largest national park in Victoria after the Alpine National Park and was proclaimed, appropriately, on World Environment Day.

The declaration of a new national park on the international day recognising the importance of the environment is an indication of the changing value we place on the land and the wildlife it sustains. The Murray River continues to support agriculture and industry, but it is also widely valued for its natural and cultural values. The river is still beset by environmental problems, including salinity, erosion, soil acidity and habitat loss, but in the national parks and conservation reserves along the river, nature now comes first.

Acknowledgements

I am indebted to Peter Menkhorst of the Parks Flora Fauna Division, Department of Natural Resources and Environment, for correctly identifying Gray's jerboa Kangaroo as an early name for what is now the eastern subspecies of the Burrowing Bettong *Bettongia lesueur graii*. I am also grateful to Linden Gillbank of the History and Philosophy of Science Department, University of Melbourne, for editorial comment.

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The Murry River in *The Victorian Naturalist*

A Thousand Miles on the River Murray

By OW Rosenhain

Read before the Field Naturalists' Club of Victoria, 16th April 1917

The squatter in the early days set about in a ruthless fashion ringing trees, without let or hindrance—to do this work must have cost many thousands of pounds; and now you see these dead monarchs of the forest for hundreds of miles on the river front, and extending back as far as the eyes can reach, one mass of white, dead timber. In places the fallen timber is so thick that cattle cannot penetrate.

After taking in sufficient fuel, a start was made for Barham Sawmills. This is a large mill on the New South Wales side, owned by the Barham Sawmilling Co. On account of the river being very low for many months previously, a fairly large stock of timber had accumulated, and they estimated there were about 1,000,000 superficial feet of timber stacked there. The manager told me that timber was becoming very scarce, and it hardly pays now to do the cutting. The nearest trees that can be felled are about ten miles from the mill.

From *The Victorian Naturalist* **XXXIV** (4), August 1917, pp 49-58.

Geomorphology of the Murray River Basin

Noel Schleiger[1]

Abstract
The Murray River is an exotic stream. Since Cretaceous time it has been both a betrunked and, more recently in the Pliocene, an engrafted river system. Since the Pliocene, the direction of the course of the Murray has been influenced by upfaulting and jointing of the rocks over which it flows. Geomorphological features such as the valley-in-valley structure, sharpened spurs, valley scroll deposits, incised meanders and valleys, bahadas and prior streams are the direct consequences of uplift, where the river rejuvenates its valley to reach its former base level in its mountain, valley or plain tract. Features of the plain tract are sinuous meanders, because of low gradients, with levee banks, ox-bow lakes, lagoons, anabranches, effluents and distributaries. Saline ground water entering the Murray River has created problems for water management of the Murray. Part of this is due to irrigation of soils developed on a salty sea bed in late Miocene and in part due to salty aquifers being cut by the Murray bed. Aeolian features in the semi-arid areas of the Riverine Plain of the Mallee and Wimmera involve parna deposits, deflated playas, parabolic sand dunes on the Lowan Sand formation and lunettes on the eastern shores of drying lakes. These are the product of a more arid climate in the Pleistocene through to the present day. (*The Victorian Naturalist* **119** (3), 2002, 95-101)

The Murray River is an exotic stream

The Murray River is the major river in Australia. It drains an area of more than 1,020,000 km^2 and is 2560 km long from source to sea. When combined with the Darling River, the tract is 5250 km, the fourth largest in the world after the Nile, the Amazon and the Mississippi-Missouri system (Twidale 1968). The average runoff per unit area is only 4% of that of the Danube Basin in Europe, which emphasizes the arid or semi-arid nature of the catchment. While the average rainfall over the whole catchment is 425 mm per annum, only 5% of the total catchment exceeds 750 mm per annum. Most of the high rainfall is over the Kosciuszko and Victorian alpine plateaus.

The Murray is thus an allogenic or exotic stream, for it rises in high rainfall areas, giving it sufficient flow to pass through the semi-arid desert regions of the Victorian and South Australian Mallee, where it has no tributaries, to reach the sea at Goolwa on the Coorong. Over this tract, water loss is mainly by evaporation and partly by downward percolation into the porous rocks of its bed and banks. Lake Victoria has an annual evaporation rate of 1500 mm, yet its annual rainfall can vary from 250 to 875 mm.

The Murray Gulf

The Murray River, as we know it today, developed in the Pliocene Period 2.5 Mya (millions of years ago) (Twidale 1968). When Australia began drifting from Antarctica 65 Mya (White 1999) much of Victoria south of the Great Dividing Range was successively transgressed by shallow seas. Also at that time, the Murray Gulf, occupying the south-west part of the Murray-Darling Basin, was inundated by the sea.

Hills (1975) referred to these shallow transgressions as formed by general downwarping or epeirogenic movements (from the Greek *epeiros* = mainland or continent). Such movements can be simple uplift or depression, tilting or broad warping which affect wide regions rather than narrow belts (see Fig. 1).

Within the Murray Gulf, marine sediments began from Middle Palaeocene and continued through to late Miocene when the sea retreated in response to the epeirogenic uplift of the bordering highlands.

A series of parallel to sub-parallel stranded coastal ridges successively developed as the sea retreated over a period of falling high sea levels.

Stratigraphy of the Murray Gulf

A detailed stratigraphy of the Murray Basin is described by Lawrence and Abele (1988). Figs 2 and 3 summarise the structure and relative ages of the sedimentary groups and members. The Australian depositional stages and the foraminiferal zones which date them are indicated in the right-hand column of Fig. 3.

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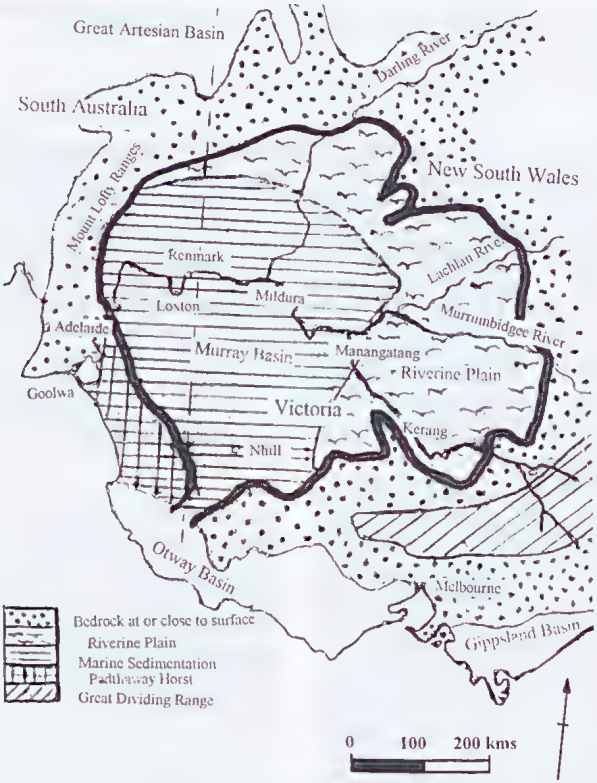

Fig. 1. The Murray Gulf from Palaeocene to Miocene time. The rivers enter the Gulf via separate mouths.

The local changes of lithology (facies changes) across the Murray Basin from South Australia and Victoria make it difficult to give decisive orders of age for some units. The facies changes from west to east are the consequence of the gradual shallowing of the Gulf.

In general, the Renmark group is the oldest, ranging in age from mid-Palaeocene to mid-Miocene. The Ettrick Marl, and the Geera Clay to the east and on the same stratigraphic level, overlie the Renmark group. The lower part of the Geera Clay is the lateral equivalent of the Ettrick Marl. The Duddo Limestone overlies the Ettrick Marl and merges into the upper part of the Geera Clay. The Winnambool Formation overlies both the Geera Clay and the Ettrick Marl. Finally, in late Miocene, the Bookpurnong Beds marked the end of marine sedimentation in the Murray Basin.

In the Pliocene, terrestrial deposition then followed. Two units highlight this environment: the Torrumbarry Clay and the Calivil Sand.

The Torrumbarry Clay

Lawrence (1975) described this member in the Echuca North No 1 Bore (Fig. 2) from 58 to 77 m. It consists of white kaolinitic clay up to 30 m thick. It overlies the Calivil Sand and is overlain by the Quaternary Shepparton Formation. It was deposited in lakes and on the alluvial plains.

The Calivil Sand

Macumber (1972) described this member in the Calivil No 2 Bore between 86 m and 105 m. It overlies unconformably the Palaeozoic bedrock or disconformably on the Renmark Group. The Calivil Sand is of grey, poorly sorted quartz sand and gravel with a white kaolinite matrix. Quite often the member is auriferous and may contain

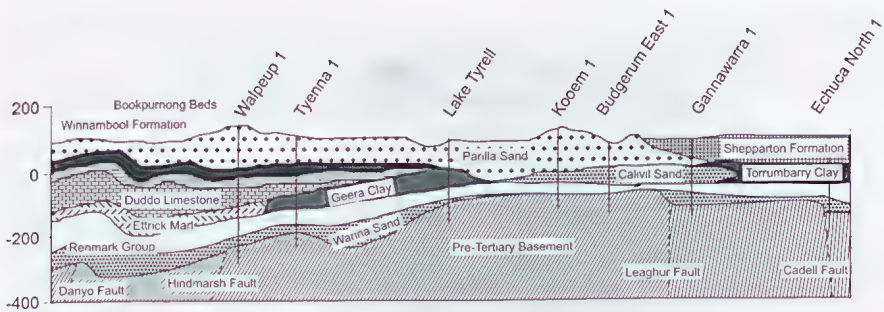

Fig. 2. The structure of the Murray Basin, following a west to east cross section from the South Australia border to Echuca, with eight key boreholes supplying the stratigraphy (from Lawrence 1975).

diatoms and plant impressions, and forms buried fan deltas up to 45 m thick. For more detail see Bowler and Macumber (1968) and Lawrence and Abele (1988).

Features of the Murray River

The mountain, valley and plain tracts of the Murray River exhibit a variety of geomorphic features which are discussed below.

Betrunked and engrafted river systems

Fig. 1 shows the extent of the Murray Gulf in relation to present day streams. Prior to the incursion of the Murray Gulf, the ancestors of the present day streams would have entered the sea, depending on their position then, as one river system as at present.

Once the Murray Gulf was established, these streams would have debouched into it by separate mouths, e.g. Fig. 1 shows the Murrumbidgee and Darling as a betrunked river system.

In the Pliocene, when the sea retreated, the Murray and Murrumbidgee joined as one. At Wentworth, the Darling joined the Murray to complete the system, and then flowed across the former sea bed to be deflected by the elevated Flinders-Lofty block to reach the sea at Goolwa, South Australia on the Coorong. This stream system is an engrafted river system for the Murray and its tributaries engrafted a new course over the former sea bed, the slope of which must have been to the north-west, then westerly and finally southerly.

Twidale (1968) shows the Murray River deflected by the Morgan fault. The Murray was defeated at Morgan, deflecting it in a southerly direction to Goolwa (Fig. 4a).

Defeated stream

The Cadell Tilt Block

The diversion of the Murray River north-east of Echuca is an example of a defeated stream. Harris (1938) describes 'the great bend of the Murray River makes to the south when about 48 km NE of Echuca'. His fig. 1 shows the Cadell Tilt Block uplifted along the Cadell Fault which runs north-north-east along the Colbinabbin Range of Cambrian greenstones to Deniliquin.

The now dry segment of Green Gully which crosses the westerly-tilted uplifted-block from Mathoura is known as a wind gap. The Moira Marshes at the base of the Cadell Tilt Block, with its outcrop of alluvium, marks the ponding of the Murray just west of its diversion point (Hills 1975; Bowler and Macumber 1968).

The North West Bend at Morgan, SA

There is much debate among geologists about whether the southerly deflection of the Murray at Morgan is the result of defeat faulting on the eastern margin of the Lofty Ranges. Twidale (1968) states 'the Murray makes a sharp turn southward in response to a series of low north to south fault escarpments located within the Murray plain' between Morgan and Blanchetown which appears to be a complex but well marked fault zone.

Williams and Goode (1978) proposed that before uplift of the Lofty and Flinders Ranges an ancient Murray River extended across the line of these ranges to a major delta in the Spencer Gulf. Brown and Stephenson (1991) have made a comprehensive study of the Murray Basin and

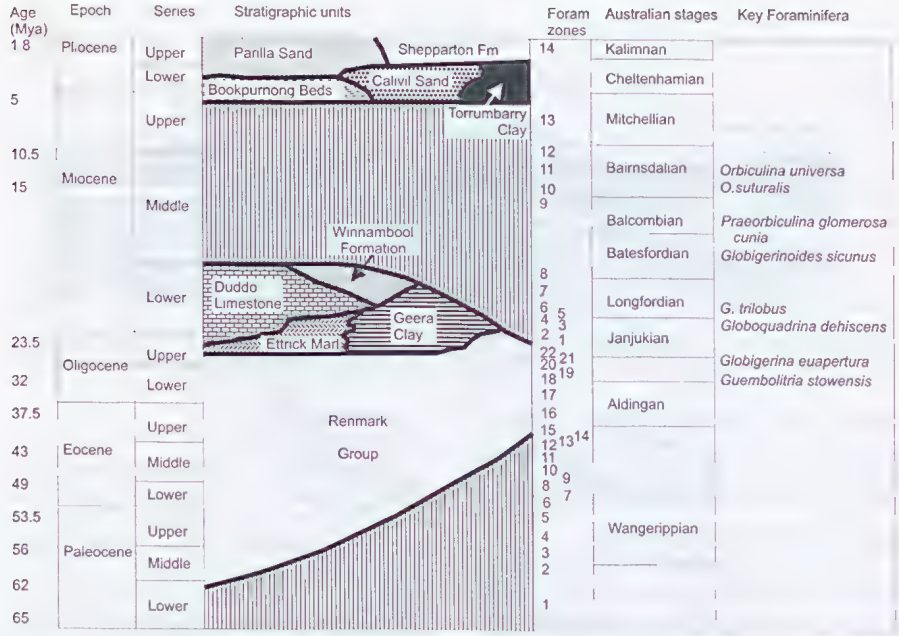

Fig. 3. Geological age-correlation chart of the stratigraphic units of the Murray Basin.

argue that this event was unlikely in the Cainozoic era. The evidence of borelogs suggests that the precursor to the modern Murray emptied into the Buccleuch Embayment at least from the Eocene. Therefore, if Williams and Goode (1978) are correct, the trans-Lofty tract would be in the Cretaceous or earlier. For more detail on this debate see Brown and Stephenson (1991). These authors argue that in the late Miocene a marine transgression which persisted into the early Pliocene to the mouth of the Murray was located near the geographic centre of the Murray Basin. This mouth migrated westerly along the course of the present Murray River as the sea began retreating from the basin. About 2-5 Mya tectonism in the western Murray Basin led to the formation of Lake Bungunnia which ponded the Murray at Morgan (Fig. 4c). About 0.7 Mya the lake waters retreated and the Murray proceeded along a southerly downstream course from Morgan following a glacial sea level drop.

Brown and Stephenson (1991) stress that the western mouth hypothesis did not occur for the ancient Murray at any time within the Cainozoic. So whether the Murray River at Morgan is a defeated stream is a paradox, as it has all the features of one.

Anastomosing streams

There are streams along the Murray in its riverine plain which form a network of widely spaced streams, large enough and long enough to rank a name. These streams have diverged from the Murray to join it further downstream, e.g. Gunbower Creek and Barr Creek. Such streams are known as anabranches.

Another type of diverging channel may terminate in a shallow lake or swamp. This is known as an effluent, e.g. Chalka Creek in the Hattah-Kulkyne National Park terminates in part at Lake Lockie one of the Hattah Lakes. In North West Victoria near the border with NSW and SA, Lake Victoria terminates Rufus River, which leaves the Murray and flows northerly. Toole Creek actually leaves the Murray River in NSW and joins the Wakool River in the Riverina. This is a distributary stream.

These anastomosing streams have levee banks built up on either side of the stream at flood time. During flood time, erosion

through a levee bank can allow the distributary to take an entirely new course as the channels are split and shifted. This allows a large area to be covered very thickly with alluvium, as occurs between Kow Swamp and Lake Charm.

Valley-in-valley structure

Between Mannum and Morgan in South Australia, the Murray Valley shows valley-in-valley structure, which suggests there are two base levels due either to epeirogenic uplift of the area, or in response to a drop in sea level. The first base level was a valley cut in the mature landscape before uplift or sea level lowering. The second base level is the stream today, a valley incised in the former valley. The first base level was cut in Pliocene times, for Twidale (1968) reports small outcrops of cross-bedded sandstones 6-7.5 m thick scattered over the cliff tops. There is an oyster bed at the base of the cross-bedded sandstone of Pliocene age. These Pliocene sediments have not been formed outside the confines of the wider valley, and were laid down in a narrow estuary, far inland up what is now the Lower Murray Valley.

Influence of bedrock jointing

Geomorphologically, joints are important as they form lines of weakness which can be exploited by weathering agents, especially water and wind. The pattern and spacing of the joint pattern (i.e. the texture of the joint system) are imposed on the pattern of relief. The geometry and spacing of joints vary within the same rock and certainly from one rock to another. The Miocene calcarenite (sandy limestone) forming the Murray cliffs markedly show joint blocks exposed in the cliffs. This joint pattern has been picked out by the Murray in SA (Fig. 4a, b).

Sharpened spurs and valley scrolls

The Murray reaches maturity when the amplitude of its meander belt is equal to the width of its valley floor. The Murray has incised a valley through the hills, where it is still cutting laterally into its banks to form accentuated or sharpened spurs, then swings away to the other side and laterally corrades hills on the other side. In so doing it deposits valley plain

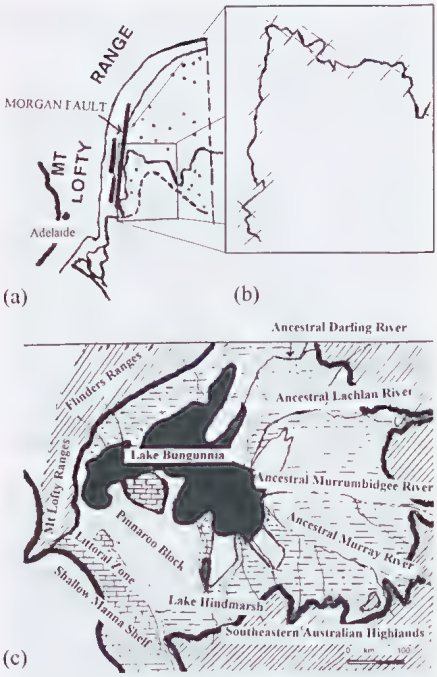

Fig. 4. (a) The Murray River deflected southerly by the Morgan Fault (after Firman 1966). (b) Directional control of the Murray tract by jointing in the Miocene sediments (enlargement of the frame in a) (after O'Driscoll 1960). (c) Palaeodrainage of Murray Basin in late Pliocene to early Pleistocene (2.5-0.7 Mya). The Murray system engrafted partly across the old sea floor to enter Lake Bungunnia. After 0.7 Mya an exit drainage line developed west of the Pinnaroo Block to drain the lake into the Southern Ocean and hence the modern Murray tract (after Brown and Stephenson 1991).

alluvium between the two zones of lateral corrasion marked by the sharpened spurs. These zones of alluvial deposition are known as valley scroll deposits (Hills 1975).

Alluvial fans or alluvial cones

The Murray shows valley-in-valley structure west of Wodonga. Tributaries entering the upper terraces of the Murray drop their sediment on approaching the Murray in the form of a flat cone. If several tributaries build alluvial cones side-by-side, an alluvial apron will form sub-parallel to the upper edge of the terrace. This is known as a bahada (Holmes 1969). If uplift continues or the Murray corrades its bed vertical-

ly lower, the tributary incises the flood plain and may even build another alluvial cone at a lower level (Hills 1975).

Parna deposits

Parna is a wind blown silt deposited in many parts of southern Australia by rain after dust storms, especially in the Pleistocene when the climate was more arid. Wide areas of the Murray Basin are covered at the surface with a layer of clay-loam called parna. It is like the loess of China but of a pallid grey colour around Melbourne. Areas of consistent loss of dust and sand are said to be deflated. In the northern plains are small barren swales, or 'scalded' areas which are believed to be formed by the deflation of salt-affected soils during dust storms.

Mostly sand is moved by saltation with jumps at about 25 to 30 cm above the surface. Strong gale-force winds carry sand along the ground, forming aeolian sand ripples with wave lengths of 9 to 12 cm. Such sand can blast and polish heavier pebbles and wear flat, sloping surfaces on them. These pebbles are known as ventifacts.

Lakes and lunettes

Hills (1940) was the first to document lunettes. These are crescent-shaped ridges on the eastern shores of lakes. They were first described by Major Thomas Mitchell from Green Lake and Dock Lake near the Grampians in Western Victoria. They are widespread in Australia south of latitude 32°S, and there are even some in Tasmania. They differ from sand dunes in consisting wholly of clay-loam on the eastern shores of lakes in semi-arid areas. The summit is broadly rounded. The highest part is closer to the lake shore than the outer margin (horns). They curve parallel to the smooth curve of the lake shore on the eastern side. They are due to beach erosion by westerlies when the lake level is seasonally low. In cross section, lunettes are typically asymmetrical, with the steeper slope facing the lake. The bedding in lunettes is generally parallel to the surface apart from where it is truncated on the lake-facing side.

Lunettes are built of granular aggregates of clay and silt on the lake floor when the water dries up, leaving salts accumulated on the lake bed as pellets of clayey material. Clay pellets driven by the prevailing west and south-west winds mantle over the accumulating dune. The majority of Victorian lunettes, including many examples between Kerang and Swan Hill, are believed to have formed between 15,000 and 17,500 ya (Bowler and Macumber 1968). Around Boort, the younger ages of lunettes suggest that the special conditions for lunette formation did not occur there until later. In some lakes, younger lunettes formed in sequence as the lake shore shrank back, or several smaller lakes formed within the one larger basin.

Salinity in the Murray River

Lakes consistently fed by streams, yet inadequate to cause the lake to overflow, accumulate all salts brought in so that their waters become highly saline. When these lakes dry out they become clay pans or playas. If they are salty, yielding crystals of halite (sodium chloride) and gypsum (hydrated calcium sulphate), then they are salinas, e.g. Lake Tyrell near Sea Lake on the floor of the Murray Basin.

In the Wentworth-Mildura area of the Murray and in South Australia between Renmark and Morgan, groundwater from springs seeps into the bed of the river. Below normal river level the springs are not visible. Some of these waters are saline. Attempts are being made in the Sunraysia area to intersect these saline aquifers and stop them from entering the Murray. The saline water is pumped into playas, where it is evaporated and the salt is harvested. This has minimized saline water entering the Murray in the Mildura area.

Summary

The geomorphic features described in the Murray Basin are of two types: tectonic structures, which have influenced the direction of the Murray tract; and semi-arid features involving aeolian and fluviatile processes due to the exotic nature of the river system.

Tectonic structures

Both epeirogenic movements and localized faulting have been active over the history of the Murray Basin. Epeirogenic movements are responsible for the betrunked and engrafted river system at the commencement and completion respectively of the Murray Gulf transgression.

Faulting of uplifted blocks such as Cadell and the Morgan faults has been effective in diverting the course of the Murray. Joint directions have been responsible for the zig-zag course of the Murray in South Australia. In its mountain and valley tract upstream from Wodonga, valley-in-valley structure has produced river terraces in response to either lowering of sea level or epeirogenic uplift of broad areas. In such a situation, fault aprons and bahadas can result from higher bankful discharge and runoff. Incised streams, valley scrolls, and sharpened spurs are common in uplifted, rejuvenated areas of north-east Victoria and South Australia.

Semi-arid features

Fluviatile features

The lack of tributaries joining the Murray is a feature of the Mallee and Wimmera. The Loddon and the Avoca Rivers fail to reach the Murray. Due to the gentle slopes, levees and sinuous meandering with ox-bow lakes, lagoons and cut off meanders are numerous. Anabranches, effluents and distributaries are common between Echuca and Renmark (Fig. 5).

Aeolian features

Parna from the precipitation of rain following dust storms, parabolic dunes on the Quaternary Lowan Sands, as well as lunettes on the eastern margins of lakes, and swamps testify to the dominance of wind in the dry summers from the Pleistocene through to modern times.

Irrigation and movement of saline ground water into the Murray have increased the salinity of the Murray since European settlement. The problem is complex and costly to solve. On the positive side, the Murray Basin could be important for the harvesting of earth resources in the 21st century. Heavy minerals, e.g. magnetite and ilmenite, are in evidence from prospecting projects. As well, granite and good quality gravel, lime, sand and clay deposits may lay the basis for building and engineering projects.

Acknowledgements

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Fig. 5. Anabranches, effluents and distributaries in the plain tract of the Murray.

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Floodplain Wetlands: the Jewels of the Murray River

Rhonda Butcher[1] and Michael Reid[2]

Abstract

Wetlands and billabongs of the Murray River floodplain are intimately connected with the mainstream, and whilst this may imply a degree of similarity, work over the past 20 years has shown that this is not necessarily the case. While billabongs are formed by the river, the physical and chemical gradients of the river and floodplain wetlands are quite different and thus the biological communities are quite different. This paper briefly describes some of the ecological differences between the mainstream and the floodplain wetlands touching on the importance of connectivity, disturbance, and the variability of the floodplain communities. (*The Victorian Naturalist* **119** (3), 2002, 102-107)

Introduction

Seasonally or intermittently flooded wetlands and billabongs are common in floodplain ecosystems and are important functional components of the Murray River (Fig. 1; Hillman 1986). Over 7000 wetlands covering an area greater than 200,000 ha have been mapped along the length of the Murray River downstream of Hume dam, with half of that area constituting floodplain wetlands (Pressey 1990). Billabongs are probably one of the best-known aquatic habitats in Australia, and are a major feature of the 300 kilometre long, confined floodplain from the Hume dam to Tocumwal. Downstream of Tocumwal tectonic activity, principally uplift of an area known as the Cadell block around 60,000 years ago (Page *et al.* 1996) has contributed to the formation of three major alluvial fans: the Barmah, Wakool and Gunbower. Frequent flooding of these low-lying fans has led to the development of extensive floodplain wetland forest (Young and Hillman 2001).

In 1986 Terry Hillman published a book chapter simply entitled 'Billabongs' in which he highlighted the diversity and productivity of billabong communities and demonstrated their distinctiveness from those of the mainstream Murray River. He lamented our lack of understanding of these systems, and whilst our understanding of the ecology of billabongs and other floodplain wetlands remains limited, it has improved. Billabongs have a unique place in Australian folklore, and they, along with other floodplain wetlands, have been the focus of considerable scientific interest and research in the past 15 years.

Billabongs are floodplain wetlands that are formed by the geomorphic action of the stream. Most billabongs are old sections of the main channel formed by meander cutoff or channel avulsion. Some may even act as anabranches during periods of high flow. Cut-off meanders can be quite deep thus forming unique deep-water billabongs, which can retain water for much longer than most floodplain wetlands. Other smaller billabongs may be formed in floodplain depressions such as scroll swales or when smaller tributaries dry out to a series of pools. Superimposed upon this variety of form is that created by the process of sediment deposition, which leads to a mosaic of billabongs of various shapes and depths across the floodplain. The process of infilling appears, in many cases, to be very slow, meaning that individual billabongs can be very old. Radiocarbon dating of billabongs on the Murray River suggests that they have been in existence for up to 7000 years (Ogden *et al.* 2001). Even more impressive, dating of two billabongs on the Goulburn River indicates they were cut off from the mainstream over 12,000 years ago – these billabongs remain more than three metres deep (Ogden *et al.* 2001; Reid in press).

Floodplain wetlands have been variously categorised according to a number of systems, but mainly reflect the water regime. They can have water for varying lengths of time, and are generally characterised as being shallow, less than 2 m deep. The elevation of the floodplain is generally only a few metres and the lower areas will be prone to more frequent flooding events.

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Issues of connectivity

One of the features of natural floodplain ecosystems is the degree to which water and other materials move between the mainstream, floodplain wetlands and the terrestrial floodplain. Since European settlement and regulation of the Murray River there has been a physical and biotic separation of the components of the floodplain, mainly through alteration of the flooding regime. The connectivity of the system has been disrupted.

Four dimensions of connectivity are apparent in a river system as it flows from its headwaters to the sea. The first is the longitudinal or upstream-downstream dimension. The second is the lateral movement of water from the river channel into the terrestrial environment, such as occurs in floodplain areas. The third is the subsurface movement of water through porous material in the streambed both laterally and vertically into the substrata. The final dimension is temporal, reflecting the change in the physical dimensions of the various components of the river-floodplain system through the seasons and with the advent of floods and droughts.

Most stream biota have distinct preferences for specific conditions and will live, or be most abundant, where they have the greatest chance of surviving and reproducing. For example, some invertebrates are adapted to living in the cool, highly oxygenated riffle areas of uplands streams. Murray Cod prefer the warmer lowland reaches. They have been shown to like particular snags and are quite content to wander over the floodplain when there is a flood. Leeches prefer the still waters of floodplain wetlands (and farm dams in the absence of natural wetlands), and River Red Gums require certain periods of inundation in order to germinate. Some biota will occur in different areas of a floodplain system at different stages of their life history, a feature that highlights the importance of connectivity across floodplain systems.

From the headwaters of a river to the river mouth a number of physical and chemical features change. Channel gradient, mean particle size of the substrate and shading by riparian vegetation all decrease as you move downstream. On the other hand, mean flow and discharge, channel width and sinuosity all increase. In the water column, downstream decreases occur in dissolved oxygen concentration, the amount of coarse particulate organic matter and the degree of variation in water temperature, whilst turbidity, salinity, dissolved organic matter, nutrient concentrations and mean water temperature each tend to increase (Boulton and Brock 1999). The overriding influence is the directional flow of the water.

Fig. 1. River Red Gum forest in flood at Barmah. Photo by Lindy Lumsden.

The physical and chemical environment of floodplain wetlands and billabongs is determined by the water regime: when they have water (summer, winter, spring), when it arrived, how long the water stayed and how much water is present. The timing and duration of the flood pulse is a key factor in driving wetland biota life cycles (Reid and Brooks 2000; Young 2001). Wetlands and billabongs are relatively closed systems and lack the longitudinal gradient seen in rivers. Events which affect the physical and chemical environments of these systems can, and do, occur at different times and rates (e.g. flooding/drying) even in quite geographically close systems (Boon *et al.* 1990; Boulton and Brock 1999). Water chemistry has been shown to reflect a cyclic pattern closely attuned to the hydrological regime. Thus, flooding leads to dilution of wetland waters. This is followed by gradual concentration, which becomes extreme in periods of drought. Associated with these changes are biotic patterns that also affect the nutrient cycling patterns. Considering this, billabong and floodplain wetlands are highly variable, rich and, at times, extreme environments (Hillman 1986; Boon *et al.* 1990; Reid and Brooks 2000).

Biological processes – primary production and the microbial loop

When water arrives it triggers the release of a pulse of nutrients from the sediments. At the same time plants and algae germinate from the seed bank in the sediment of the wetland and begin to grow. The nutrients provide food for the bacteria, which then begin to break down the terrestrial organic material that has been inundated. The microbial loop is a very important component of wetland function. It was once thought that bacteria's main role in ecosystems was as decomposers of dead and dying matter, thus making the nutrients available to other consumers. However, research has shown that microbes are actually a food source in themselves and form part of the food web, thus the term microbial loop has become popular. Biota which feed on bacteria include protozoans, such as small flagellates and ciliates, and rotifers which are in turn eaten by bigger invertebrates, and so on (Boulton and Brock 1999).

The main groups of primary producers include both micro and macroscopic forms. The macroscopic primary producers are the water plants, which include both submerged and emergent forms that grow in shallow areas. The distribution of aquatic plants is strongly determined by water depth and clarity because they are limited by light availability. The microscopic primary producers include two major groups, the periphyton, which grow attached to the sediments and other submerged surfaces (e.g. woody debris, plants) and the phytoplankton, which occur in the water column. In the Murray River and the associated deep billabongs today, the bulk of primary productivity appears to be carried out by phytoplankton (Ben Gawne pers. comm.; Reid *et al.* in press). However, there is evidence from the sedimentary records of several Murray River billabongs that prior to the arrival of Europeans aquatic plants and periphyton were much more important primary producers (Ogden 2000; Reid *et al.* in press).

Habitat zones within wetlands and associated invertebrate assemblages

Generally wetlands can have up to four readily identified habitats or microhabitats: the water surface, the open water zone, the profundal zone and the littoral zone.

The littoral or edge zone is characterised by relatively coarse sediments and a complex habitat structure. The complex structure arises because large plants can grow in this zone as it usually equates to the euphotic zone, which is defined as the depth to which light penetrates in the water column to sustain/support photosynthesis. An abundance of woody debris often contributes further to the habitat complexity of this zone. The littoral zone is generally the most biologically diverse region within a wetland. For this reason, along with more practical reasons related to access, this zone is often the focus of biological study.

The region of the wetland that lies beyond the euphotic zone is known as the profundal zone. There is not sufficient light at this depth to support photosynthesis so no plants grow here. Bacteria, detrivores and the animals that feed on them predominate within this zone. The sediments are generally finer and there is less structural diversity than in littoral areas. The separation between littoral and profundal zones is highly variable, and in many shallow clear water wetlands a true profundal zone may not exist (Boulton and Brock 1999).

The air-water interface or the neuston of the water surface supports a number of specialised biota. Virtually all of the biota adapted to the neuston are predators, and come mainly from the Hemiptera (bugs) and the Coleoptera (beetles). Some biota are temporary members of the neuston as they are air breathers. These include the culicid mosquito larvae, diving beetles, and other bugs. Because these animals are air breathers it is believed they are relatively tolerant of poorer water quality, especially low oxygen levels (Boulton and Brock 1999).

The open water column is often referred to as the pelagic or limnetic zone. Invertebrates found in the open water zone can be divided into the nekton, generally macroscopic organisms that are strong, active swimmers, and the zooplankton, smaller organisms that are generally weaker swimmers or that passively drift or float within the water column. Many zooplankton such as rotifers, water fleas and copepods are grazers, and can be found in large numbers in the water column (Boulton and

Brock 1999). The nekton includes the fish and the larger invertebrates, such as many bug and beetle species, that feed on the zooplankton or on each other.

The micro-invertebrates of floodplain wetlands and billabongs are particularly well known due to the efforts of Russ Shiel and his colleagues. A considerable body of taxonomic and ecological work has shown that, not only are there large numbers of species present in these habitats, but that many which were thought to belong to cosmopolitan species are actually endemic to Australia. The most diverse billabong assemblages are not planktonic, but are epibenthic and epiphytic in the littoral zone (Hillman and Shiel 1991; Green and Shiel 1992; Shiel 1995; Shiel *et al.* 1998).

How changes in the water regime affect biota and the broader functioning of the floodplain ecosystem are questions on which considerable work has focused. A number of studies suggest that wetland invertebrate communities are affected by periodicity, seasonality and duration of flooding (Boulton and Lloyd 1992; Nielsen *et al.* 1999; Quinn *et al.* 2000). However, the mechanisms driving the observed patterns are likely to be complex. For example, a recent study by Quinn *et al.* (2000) compared the changes in invertebrate communities of temporary and permanent wetlands on the Murray (regulated) and Ovens (unregulated) floodplains over time following flooding. They found that distinctions between permanent and temporary wetlands were clear and persistent for Murray wetlands but that no distinction could be made between temporary and permanent wetlands on the Ovens floodplain, even for the samples taken just one month after flooding. This suggests that some of the mechanisms linking biota and flooding regimes operate at large spatial scales.

One area of great interest is how changing flooding regimes may affect the emergence (hatching) of resting stages of invertebrates and plants from floodplain sediments following inundation. The low and unpredictable rainfall that characterises much of the Murray-Darling basin means that aquatic organisms must be able to persist through long dry periods. Many do so by producing desiccation-resistant eggs or seeds that can lie dormant in dry soil or sediment for many years. Studies in Australia (Boulton and Lloyd 1992; Jenkins and Briggs 1997) and overseas (Hairston and De Stasio 1988; De Stasio 1989; Hairston *et al.* 1995) show that eggs estimated to be up to 300 years old can hatch under suitable conditions. The long lived nature of the egg and seedbanks provide not only the refuges from extended periods of drying or drought but also a means of maintaining genetic, phenotypic, species and community diversity (Ellner and Hairston 1994; Hairston *et al.* 1996; Leck and Brock 2000). However, despite this apparent resilience, several experimental studies have shown that spatial variation in the number and variety of invertebrates emerging from flooded sediments can be partly attributed to variation in the flooding history of those sediments (Boulton and Lloyd 1992; Boulton and Jenkins 1998; Nielsen *et al.* 2000). Thus, changes in flooding regime associated with river regulation appear to have the potential to affect the viability of the egg bank and hence the abundance and diversity of emergent communities.

Concluding remarks

One of the main controlling elements in structuring aquatic communities is disturbance. In Australia we have high natural disturbance with frequent floods and droughts, which are believed to be one of the major determinants of aquatic community structure. Human disturbance compounds environmental change and is superimposed upon natural variability. Virtually all of our rivers and streams have had their flow regime altered in some manner, usually by diversions or dams. Altered volumes and seasonality of flows radically change the natural settings of rivers and streams and the delivery of water to the floodplain and its associated wetlands. These changes have, in turn, been implicated in the loss of native species and an increase in invasive exotics that are apparently better suited to the new conditions (Stanford 1996).

The cumulative effect of these disturbances is the decoupling of the complex interactive pathways that are characteristic of the four dimensions of connectivity along rivers in large basins (Stanford 1996).

River regulation is just one example. It decouples the longitudinal and lateral

dimensions of rivers. In the Murray, for example, we have whole sections of river that have been converted from flowing lotic environments to a series of lentic weir pools. The weir pools act as a migration barrier for fish and other animals, they act as flood and nutrient sinks and they can stimulate biophysical consistency in downstream sections of the river. A difficulty associated with disturbance is identifying causality. Particularly in lowland and midland reaches of rivers, attributing alterations in aquatic community structure to any one disturbance is quite difficult. Increased salinity, increased turbidity and sedimentation, alterations to flow regimes and water quality are all things that tend to happen together, so separating out one culprit can be quite a challenge at times.

Billabong and wetland environments are extremely variable and this heterogeneity is also reflected in the biotic community. Even when the floodplain is inundated and would appear on the surface to be a homogeneous single wetland environment, environmental patchiness still exists as different biota respond differently to the flood event. This variability makes the life of a natural resource manager quite difficult. For example if a manager is trying to assess the impact of an environmental water allocation to a floodplain system, the scale at which variables are measured and recorded will have a great influence on what information can be gained. Biota operate and respond at different scales and rates: this spatial and temporal variability is a critical feature of all wetland environments and needs to be carefully considered when undertaking any ecological assessment of a wetland (Weins 1989; Schneider 1994; Butcher *et al.* in prep).

Floodplain wetlands and billabongs form the aquatic component of the floodplain and have distinct differences in the physical and chemical gradients and in the biological processes and communities compared to the mainstream. It is easy to think of them as separate entities, but all three major components (terrestrial floodplain, aquatic floodplain habitat and the mainstream) of floodplain river systems such as the Murray are interdependent. They are highly complex and variable, fascinating environments: jewels that we should learn to appreciate and treasure.

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Habitat Change in River Red Gum Floodplains: Depletion of Fallen Timber and Impacts on Biodiversity

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Abstract
Fallen timber, or coarse woody debris, is a major habitat structural element for animals and plants throughout forested areas worldwide. Fallen timber volumes have been massively manipulated both through direct means (fire-wood collection, fuel reduction) and through indirect activities (silvicultural management preventing trees reaching senescence). Work in our laboratory has focused on assessing the extent of fallen timber depletion in River Red Gum *Eucalyptus camaldulensis* floodplain forests of the southern Murray-Darling Basin. We estimate that contemporary fallen timber loads average about 16% (about 19 tonne/ha) of loads prior to European settlement. We also have been investigating relationships between fallen timber loads and biodiversity of both vertebrates and invertebrates. Our observational and experimental results indicate that loads at least twice current levels exert a positive influence on a number of ecologically critical species (e.g. Yellow-footed Antechinus *Antechinus flavipes*, Brown Treecreeper *Climacteris picumnus*). Therefore, restoration targets of 40–50 tonne/ha seem reasonable objectives for managing this critical element of habitat structure. (*The Victorian Naturalist* **119** (3), 2002, 107-113)

Introduction

Ecological problems have become increasingly evident in lowland rivers, mostly resulting from human-induced habitat changes in the streams, their riparian zones, floodplains and in the broader catchment (Dexter *et al.* 1986; Harding and Winterbourn 1995; Harding *et al.* 1998, 1999). Many human impacts have resulted in simplified habitats. Simplification has involved diminution of variability and magnitude of important ecological processes, as well as changes in structural attributes of habitats. One example of the former is river regulation, which reduces flow variability and may even reverse seasonal flow patterns (Close 1990; Lake 1995; Ward and Stanford 1995). In terms of habitat structure, one of the most striking impacts on floodplains has been the general reduction of structural variety, especially loss of mature trees, ground cover and natural litter or 'debris'. Here, we focus on the loss of fallen timber (also known as coarse or large woody debris) from floodplain habitats and evaluate effects of loss on biodiversity.

Fallen timber on floodplains is ecologically important because it: (1) yields structural habitat for fauna during both dry peri-

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ods (e.g invertebrates, non-aquatic vertebrates, Hawkins *et al.* 1983, Stanhope *et al.* 1987) and during inundation (e.g. fish, aquatic invertebrates and microorganisms; Bryant 1983; Thorp *et al.* 1985; O'Connor 1991; Fausch and Northcote 1992); (2) may be a nutrient source for invertebrates, flora and fungi (Bilby 1981; Culp *et al.* 1996; Edmonds and Marra 1999); and (3) traps fine debris, in-flowing nutrients and sediment, producing complex microhabitats for animals (Harmon *et al.* 1986; Andrus *et al.* 1988; Aumen 1990; Naiman and Décamps 1997). Thus, fallen timber provides shelter and nutrition for many invertebrates, reptiles, small mammals and fishes.

The paper is divided into sections covering the current status of fallen timber on floodplains of the Murray River and its major tributaries in Victoria and New South Wales, and how that status might relate to pre-European fallen timber loads. We then discuss results of some observational and experimental studies involving the responses of terrestrial invertebrates and vertebrates to the presence of fallen timber in floodplain habitats.

Fallen timber—now and then

In River Red Gum *Eucalyptus camaldulensis* forests of the Murray-Darling Basin on public land alone, c. 115,000 tonne of firewood and c. 122,000 tonne of timber (including wood chips) are legally removed annually (Crabb 1997). The total forested area also is much contracted. It appears that in the past, floodplain forests were more open with fewer trees per unit area. These forests probably had a substantially greater number of large, senescent trees (Parkinson and Mac Nally 2000), which produce the greatest volumes of woody debris through natural bough abscission and tree death (Jacobs 1955). Centuries-long silvicultural exploitation has led to a virtual absence of large, old trees. Thus, recruitment of fallen timber also is much reduced. These observations suggest that fallen timber is now much depleted in floodplain forests of the southern Murray-Darling Basin, but what is the magnitude of that depletion?

To assess current fallen timber loads, we used a combination of aerial surveys and ground-truthing (Mac Nally *et al.* in press b). Some 2442 km of the 2987 km of the reaches were surveyed in this way: Murray (Albury to Murray Bridge), Murrumbidgee (downstream of Wagga Wagga), lower Darling (downstream of Menindee), Lachlan (Hillston to Murrumbidgee confluence), Wakool (downstream of the Edward River), Edward (Deniliquin to Wakool confluence), Darling Anabranch (downstream of Popilta), lower Goulburn (downstream of Nagambie), Loddon (Bridgewater to Little Murray confluence), Campaspe (Lake Eppalock to Murray confluence) and Avoca (downstream of Charlton) rivers. Much of the residual 18% (Gunbower Island, Barmah forest, Millewa forest, lower Goulburn south of Nathalia, lower Ovens floodplain around Peechelba) was too thickly forested to survey from the air. The thickly forested areas were surveyed using at least thirty 0.5 ha plots in each named area. Surveys were conducted on both public land and on private leasehold properties on the floodplains.

Fallen timber estimates from the aerial survey

Fallen timber loads on more than half of the surveyed area were estimated from aerial-survey data (119,480 ha). We found that the average fallen timber density was about 19 tonne/ha. This figure is a little less than the complete complement of timber of three, one-metre diameter (at breast height) River Red Gum trees spread over each ha (c. 21 tonne/ha). The 19 tonne/ha value is consistent with the mean of the ground-truthed sites, which was 22 tonne/ha. The total amount of fallen timber on the floodplain outside of the forest blocks was about 2,262,900 ± 100,000 tonne.

Fallen timber in the major forest blocks

Barmah had the greatest density of fallen timber on the southern Murray-Darling floodplain, averaging over 24 tonne/ha. The average in the lower Goulburn area was about half of the Barmah value, and the other areas were between these extremes. The estimated amount of fallen timber at Barmah is about 741,900 tonne, but may be as little as 565,700 tonne or as much as 957,700 tonne given the uncertainties in the estimation process. In the five forest-block areas, comprising 101,600 ha, the mean estimate is 1,912,200

tonne of fallen timber. The range of estimates was 1,483,300 tonne to 2,393,500 tonne. This wide range is due to the small areas of each forest actually surveyed using transects in the forest blocks: between about 0.1% in Barmah and Millewa (hence confidence limits of about 25% of the mean) and, at most, 0.6% on the Ovens floodplain.

Total fallen timber load estimates

Combining results from the blocks and aerial survey, the total fallen timber on the southern Murray-Darling floodplain that we surveyed was about 4,175,100 tonne, with 95% confidence limits of 3,645,000 to 4,753,600. Average density of fallen timber is about 19 tonne/ha.

Pre-European levels of fallen timber on floodplains

An exhaustive examination of plans, forestry records and historical literature suggests that the structure of River Red Gum communities has changed considerably. However, there are virtually no early historical data pertaining to River Red Gum forests, and relatively little is known of the dynamics of woody debris in these environments. In lieu of historical information, a useful surrogate approach is identification of sites at which modifications following European settlement have been minimal—such sites may yield the best picture of pre-European fallen timber loads. Robinson (1997) found that standing crops of live trees, fallen timber and stags were all significantly higher in inaccessible, old-growth areas than in managed areas in the Millewa State Forest, southern New South Wales. Levels of fallen timber were about five-fold higher in old-growth areas (125 tonne/ha), while the values for managed areas were comparable to those reported here (20-30 tonne/ha). There appear to be very few other existing sites upon which to base historical estimates, given the relative accessibility of the floodplains and the demand for firewood and timber over the past two centuries. We think that Robinson's figure is a reasonable one because it was not greatly different from the maximum load (95 tonne/ha) we recorded in 516 half-hectare transect surveys along the Murray River and tributaries. The figure also is low by comparison with overseas loads (Maser and Sedell 1994), so it is unlikely to be a gross overestimate.

If the old-growth-site data of Robinson's (1997) study are representative of pre-impact levels, then a fallen timber density of about 125 tonne/ha probably is reasonable. Such a density implies a loss of between 23,000,000 and 24,000,000 tonne for the 221,080 ha considered here, or the equivalent of 3.3 to 3.4 million River Red Gums of one-metre trunk-diameter in the form of fallen timber. This amounts to the total timber standing on 115,000 ha of mature, old-growth River Red Gum forest given representative standing-timber woodloads in contemporary, managed forests (200-300 tonne/ha), which is about the amount of standing timber on over half of the area that we measured!

Loss of fallen timber: impacts on biodiversity

Our concern about fallen timber loads in the floodplain forests is mostly to understand how broad-scale, intensive change in a major structural element of habitats affects the capacity of animals (and plants) to persist. To address this question, we have used a number of observational and experimental methods to try to link biodiversity with different fallen timber loads in three main areas of the southern Murray-Darling Basin with extensive remnant River Red Gum forests: Gunbower Island, Barmah Forest and the Ovens River floodplain (all in northern Victoria, Australia). The first two forests lie along the Murray River itself, while the latter straddles a major, essentially unregulated tributary of the Murray River.

Terrestrial invertebrates

Due to their comparatively small physical size and limited mobility, terrestrial invertebrates may exhibit strong responses to localized habitat changes. Invertebrates also represent the vast majority of biodiversity (Sala 2000). These features make invertebrates important subjects for research on the impacts of habitat-structural change. However, given that most invertebrate species respond at localised scales (Hansen 2000), the impact of any localised variability in habitat is potentially much greater than for more mobile species, such

as birds, that can 'even out' small-scale environmental change by moving to nearby or more distant locations (Mac Nally in press). Thus, the invertebrate assemblage at any given point locality is the product of a complex array of interacting factors, of which fallen timber load is just one. In addition, the sheer variety of invertebrates makes it difficult to adequately characterize invertebrate assemblages (Colwell and Coddington 1994). Through our attempts to study invertebrates in River Red Gum forests, we have encountered some novel aspects of these problems.

The invertebrate fauna of Murray Basin red gum forests reflects the geographic positioning of the forests. A large component of the fauna is composed of typical dry-sclerophyll-forest species (e.g. *Promecoderus* spp. [Coleoptera: Carabidae], Matthews 1980), but there are also riparian-zone specialists (e.g. *Tachys* spp. [Coleoptera: Carabidae], Matthews 1980, *Dolomedes* sp. [Araneae: Pisauridae]), arid-zone faunal elements (e.g. *Rhytisternus* spp. [Coleoptera: Carabidae], Matthews 1980; *Neostorena* sp.), as well as widespread species (e.g. *Rhytidoponera metallica* (Smith) [Hymenoptera: Formicidae], *Lycosa pseudospeciosa* Framenau and Vink [Aranae: Lycosidae]). There are also many undescribed species for which biogeographic affiliations cannot be attributed at this time.

We find that the various elements of this diverse fauna respond to habitat change differently. For example, the removal of fallen timber often results in forest-floor habitat that is drier and more open, which favours arid-zone species. Zodariid spiders ('knobble' spiders; Shield 2001), which are arid-zone specialists (Churchill 1998), increase in abundance and diversity in areas with reduced fallen timber loads. In contrast, certain species of lycosid or wolf spiders are restricted to areas with relatively high fallen timber loads. Thus, while the species comprising invertebrate assemblages, and their relative abundance, differ with amounts of and proximity to, fallen timber, no reduction in biodiversity per se has been identified in areas where fallen timber had been removed. We need to be wary of using species richness alone as a measure of ecological change when shifts in assemblage structure may be more informative and indicative of system change.

Those areas of the forest that have been most affected by removal of fallen timber generally are the same areas that now flood very infrequently under current flow regimes. The confounding of flood-proneness with fallen timber load makes teasing out the particular role of fallen timber in affecting biodiversity challenging. Focusing on the response of obligate saproxylic species (dead-wood specialists) is one strategy for getting a clearer signal of the impact of removal of fallen timber. This method has been used successfully in the boreal forests in Europe and North America, where saproxylic species, particularly coleopterans, represent a major faunal component (Harmon *et al.* 1986; Jonsson and Jonsel 1999; Schiegg 2000). These highly specialized beetles either feed directly on rotting timber, or on fungi growing on logs. Despite extensive sampling in River Red Gum forests, we trapped very few obligate saproxylic species. The low numbers of these species may be due to an unsuitable combination of regular forest flooding and the unpalatability of River Red Gum timber. However, despite the paucity, we found fallen timber to be an important factor influencing the composition of coleopteran assemblages in River Red Gum forests. Thus, rather than being a critical resource to a limited range of highly specialized taxa, fallen timber in River Red Gum forests has an important ecological function by providing habitat-structural complexity to a wide range of more generalized species.

Terrestrial vertebrates

We have investigated the responses of terrestrial vertebrates (mammals, birds, reptiles and frogs) to differences in fallen timber loads in the three major forests (Gunbower Island, Barmah, Ovens floodplain; Mac Nally *et al.* 2001). In each forest, seven graded (by fallen timber loads: 1.4-60.2 tonne/ha) sites were investigated over two years. These sites were chosen to reflect the maximum observed range in current loads in the forests. Our results showed that the only native, terrestrial mammal (Yellow-footed Antechinus *Antechinus flavipes*) occupied sites in significantly

higher densities when fallen timber loads exceeded 45 tonne/ha. Ground-dwelling birds and those using fallen timber are more prevalent, and in richer diversities, in the vicinity of accumulations of woody debris. Overall, fallen timber loads did not appear to relate significantly to avian patterns apart from at the local scale (i.e. near wood accumulations). Neither frogs nor reptiles seemed to be influenced by fallen timber loads. There were very few reptiles, which may reflect broad-scale depletion of fallen timber from these habitats; similar impacts are evident in wood-depleted box-ironbark forests immediately to the south of the floodplain forests in northern Victoria (Bennett *et al.* 1998; Bennett *et al.* 1999).

We also have conducted a reasonably large-scale manipulation of fallen timber loads to study causal relationships between loads and the occurrence of birds and mammals. About 1000 tonne of wood were redistributed after one year's prior monitoring to effect eight different experimental treatments in 34 one-hectare plots (Mac Nally 2001). We have established a rapid response of a near-threatened (Garnett and Crowley 2000), wood-dependent species of bird, the Brown Treecreeper *Climacteris picumnus*, whose densities increased substantially in all treatments with fallen timber loads exceeding 40 tonne/ha (Mac Nally *et al.* in press a). This value is about twice the basin-wide average for floodplains of the southern Murray-Darling Basin. It is important to conduct further work to see whether the reproductive performance of the birds also increases in a corresponding fashion (Walters *et al.* 1999). While analyses and studies are continuing, our results suggest that the Yellow-footed Antechinus has a similar preference for sites with loads exceeding 40 tonne/ha, which is consistent with our results from the observational program. Given the restricted breeding season and the retention of pouched young, we should soon be able to assess whether more wood translates into more antechinuses.

Conclusions

Implications for restoration

There are two main avenues to approaching habitat restoration. The first is to restore a system to its pre-impact state (Ward *et al.* 1999; Lake 2001), which we know little about directly. If Robinson's (1997) data are representative of pre-impact levels, then a fallen timber load of about 125 tonne/ha may be a reasonable figure. This load implies a restoration target of 27,635,000 tonne alone for the 221,080 ha considered here. The magnitude of this objective is such that it would take many decades just to be able to grow a supply of new timber to fell for this purpose!

Another approach is to try to reinstate ecological function. For example, our objective has been to relate woodloads to the diversity of animals. We need to recognise that this restricted objective addresses only biodiversity aims, so that ecosystem processes such as nutrient fluxes and primary and secondary productivity are not explicitly considered. Nevertheless, a load averaging about 40-50 tonne/ha seems to be the best target for biodiversity outcomes given our results (Mac Nally *et al.* 2001; in press a). Moreover, this figure is much more logistically feasible than the 125 tonne/ha suggested by Robinson's (1997) study—at least in the foreseeable future—for restoration of fallen timber on floodplains, and may be achieved in relatively few decades.

Restoring the ecological integrity of the lowland floodplains of the Murray-Darling basin must involve the return of the rivers and riverine environments to something nearer their pre-European-settlement condition. One of the main components of the structural complexity of floodplains, fallen timber, is effectively missing over vast areas. Restoration will be a Herculean task for many reasons, most especially because of the lack of replacement timber. Thus, not only does fallen timber need to be reinstated, but there needs to be a massive expansion of forested habitat on the floodplains to service the ecological well-being of the floodplains. In the shorter term, thought needs to be given to developing a management strategy for restoring fallen timber. For example, given a limited amount of material, how can it be best placed to begin the long road to recovery? Are flood runners to be preferred given their greater significance to both inundated and dry-phase fauna? How specific are

animals in their use of fallen timber in terms of its location on the floodplain? Is it best to augment existing accumulations or is it more effective to more widely and thinly distribute the fallen timber? The woody debris story is only at the beginnings of its rudimentary course, but our work has established that the task is a huge one because of the severity of the changes that have been wrought since European settlement.

Caution: floodplain vs in-stream fallen timber loads

Much of the river-restoration literature concentrates on in-stream fallen timber, 'snags', which are perceived to be critical elements for fish, macroinvertebrates, algae and 'biofilm'. Our focus on floodplain fallen timber should help to place the snag problem in perspective. What are the relative merits of fallen timber on floodplains and in channels? There are surprisingly few measurements of natural loads of in-stream fallen timber in Australian rivers, especially for lowland rivers (Marsh *et al.* 1999). Marsh *et al.* (1999) estimated in-stream fallen timber loads in the Edward River to be 90 ± 60 tonne/ha (0.015 m^3/m^2). Given that floodplains cover much greater areas than the associated rivers (rivers usually <100 m wide), the severity of fallen timber depletion from floodplains seems to be at least an order of magnitude worse than in-stream de-snagging. This is a critical point should restoring snags to rivers remove fallen timber from floodplains. This would be a severe and certainly misguided case of robbing Peter to pay Paul. Fallen timber management in floodplains and in the associated channels must be considered in a unified way (Mac Nally and Parkinson 1999).

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Vertebrate Fauna of Barmah Forest, a Large Forest of River Red Gum *Eucalyptus camaldulensis* on the Floodplain of the Murray River

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Abstract

Barmah Forest is part of the largest River Red Gum forest in the world, and several studies have examined aspects of its vertebrate fauna in recent decades. This paper summarises this work and gives an overview of the forest fauna along with some historical information and comments on possible effects of management practices. Altogether 35 mammal, 205 bird, 20 reptile, 10 frog and 28 fish species have been recorded in or near Barmah Forest. Bats constitute a high proportion of the mammal species. Arboreal mammals are represented by several species in generally low numbers. The only native rodent is the aquatic Water Rat, and the only small native ground-dwelling mammal is partly arboreal (Yellow-footed Antechinus). The most numerous ground-dwelling birds are those that can also feed from other substrates during floods (e.g. Brown Treecreeper). Three bird species (White-plumed Honeyeater, Striated Pardalote and Brown Treecreeper) form a high proportion of individuals in the bird community (40%). Canopy feeding insectivores are patchily distributed and their numbers are negatively correlated with aggressive White-plumed Honeyeaters, which even dominate on box ridges. Hollow-nesting birds form a high proportion (34%) of individuals in the bird community. The forest is an important habitat for several threatened species, and for large numbers of waterbirds, fish and frogs that breed there during floods. Deep spring floods provide the best breeding conditions for many of these species. River regulation, grazing and logging have all contributed to a range of historical changes. Mostly anecdotal evidence suggests loss of some mammal and bird species and more recent declines in certain waterbirds, frogs and snakes. The fish fauna is now heavily dominated by introduced species. (*The Victorian Naturalist* **119** (3), 2002, 114-132)

Introduction

River Red Gum *Eucalyptus camaldulensis* is one of the most widespread eucalypt species in Australia, commonly growing beside rivers and in ephemeral watercourses and floodplains over much of the continent (Costermans 1981; Groves 1981). It occurs as linear strips along inland rivers with more extensive stands of forest or woodland in temperate areas, including the banks and floodplain of the Murray River. The most extensive remaining stand is the Barmah-Millewa Forest (60,000 ha), straddling the Murray River between Echuca, Deniliquin and Tocumwal (Dexter 1978; Murray Darling Basin Commission 2000).

Despite the wide occurrence of River Red Gum forests and woodlands, little has been published on the vertebrate fauna inhabiting this distinctive forest type. This paper describes aspects of the vertebrate fauna of Barmah Forest. It is based mainly on multiple visits from 1977-80 (Chesterfield *et al.* 1984); intermittent observations by the authors in subsequent years; data collected during fauna studies in the 1990s (Bennett *et al.* 1994; Brown and Bennett 1995; Lumsden *et al.* 1995); results from monitoring projects undertaken by the Barmah-Millewa Forum (Maunsell McIntyre 2000; Ward *et al.* 2000; Ward 2001, in prep.; Webster 2001, in prep.); other miscellaneous documents (e.g. Cadwallader 1977); records in the Victorian Atlas of Wildlife and personal communications from naturalists. The paper aims to give an overview with details of selected studies only (e.g. quantitative area searches for land birds). The latter information has been reported previously (Chesterfield *et al.* 1984), but not analysed or presented in a widely available form. The paper focuses mainly on the Victorian side of the river, but mentions some known contrasts relating to the New South Wales side.

Barmah Forest

The forest covers 29,500 ha in Victoria, within the traditional land of the Yorta Yorta people. It is a Ramsar listed wetland, and sections were declared State Park in

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1987, with Reference Areas at Top Island and Top End (LCC 1985). The forest is dominated by River Red Gum over most of this area, and periodic floods play a crucial role in maintaining the health of these ecosystems (Fig. 1; Bren and Gibbs 1986; Dexter *et al.* 1986; Bren 1988; MDBC 2000). Stands of Grey Box *E. microcarpa* and Yellow Box *E. melliodora* grow on raised sandy ridges, and Black Box *E. largiflorens* occupies some low-lying ephemeral swamps, and the fringe of the forest block. Understorey vegetation is mostly open and dominated by grasses, with a high proportion of introduced weeds (Chesterfield *et al.* 1984; Frood and Ward in prep.). Scattered shrubs occur especially on box ridges (where some species such as Silver Banksia *Banksia marginata* are represented only on the New South Wales side) and on riverbanks. Silver Wattles *Acacia dealbata* and thickets of introduced Blackberries *Rubus fruticosus* and Willows *Salix* spp. grow mainly on riverbanks. Various aquatic plants dominate ephemeral swamps in low-lying areas, with extensive beds of Moira Grass *Pseudoraphis spinescens* forming on treeless floodplains as floods recede (Chesterfield 1986; Ward 1991, 1994).

Cattle have been allowed to graze on the Victorian side for many years, and have impacted on swamp vegetation, with Giant Rush *Juncus ingens* prospering at the expense of Common Reed *Phragmites australis* and Cumbungi *Typha angustifolia* (Chesterfield 1986). Sheep have grazed on the New South Wales side. Grazing has been reduced in recent years. Logging has proceeded on both sides of the river for many years, with railway sleepers being a major product (Dexter 1978; Chesterfield 1986). Limited logging continues in the State Park (DCE 1992).

Varying proportions of the forest are inundated when the river overflows its banks. The natural season for flooding is late winter and spring, following winter rain and snow melt in the mountains. Since the 1930s, the river has been regulated by construction of dams near Albury-Wodonga (Hume Dam, 1934) and Dartmouth (1980), and a weir at Yarrawonga (1939). The main aim of regulation has been to store water at peak flows and release it during summer-autumn for use by irrigation farmers. Hence there has been a reduction in the extent and frequency of winter-spring floods and an increase in summer-autumn flows to low-lying areas. The dam at Dartmouth was also intended to provide a capacity for flushing the river to control salinity problems downstream. Flows of water through the forest are further regulated by means of sluice gates on most creeks and major flood runners (distributary channels).

Fig. 1. Flooded River Red Gum forest. Photo by Lindy Lumsden.

Methods

In the early stages of this study, all parts of the forest were explored to gain a general picture of the fauna and its distribution. Quantitative data on land birds were obtained on six sites by searching areas of 4 ha (200 × 200 m) for an hour each in October-November 1977 (a dry year, no flooding) and October-November 1978 (a wet year, with floodwater lying over about half the forest at the time of the survey). A canoe was used to gain access in 1978, but the surveys were conducted on foot (wading in water up to neck-deep at one site).

The data were analysed by grouping species into guilds, and examining effects of sites (6) and years (2) using analysis of variance (assuming no interaction between sites and years). Five of the sites were in stands of River Red Gum on the floodplain, and one was on a sand-ridge dominated by mature Grey Box with some Yellow Box. Four of the River Red Gum stands were mature and three of them contained many large old hollow-bearing trees. The fourth site (Barmah Island) contained mature trees but few old living veterans, as intensive silvicultural treatments had killed such trees by ringbarking and poisoning over several decades. The fifth Red Gum site (burnt) was regenerating from a severe wildfire that burned ~30 ha ten years before the study, and most of the few old trees were dead.

Water birds were counted at various times during this period, and attempts were made to count colonial breeding water birds in each of these years. Small mammals were trapped at five sites in three seasons, using folding aluminium traps and small wire-cage traps (1280 trap-nights) and harp traps and mist-nets for bats (at four water-holes in January 1980) (Chesterfield *et al.* 1984). Scats and signs were recorded, and spotlight surveys were conducted on foot and from vehicles.

As part of a broad scale study of vertebrate fauna of the Northern Plains in the early 1990s (Bennett *et al.* 1998) five sites within Barmah Forest were sampled for bats and arboreal mammals. Harp traps were set for bats at each site for two nights. Spotlighting was undertaken on foot by intensively searching a 1 ha plot for 45 minutes, on two consecutive nights.

Colonial breeding water birds were counted from the air in most years since the 1980s when there was a spring flood (Ward 1993, 1996; Ward *et al.* 2000), with ground truthing where possible. Earlier records from 1955-1979 were collated by Cowling and Lowe (1981).

The first in-depth amphibian survey for Barmah Forest was conducted in 2000/01 (Ward 2001). Frogs and their breeding attempts were surveyed at night on a monthly basis between September and February by documenting vocalising species plus undertaking some limited ground searches at approximately 20 sites throughout the forest. Breeding attempts were primarily recorded from tadpoles collected from dip-net samples. This program has continued into 2001/02, with monitoring undertaken at various months throughout the year (Ward 2002).

The Department of Natural Resources and Environment has undertaken a variety of fish surveys in and adjoining the forest (McKinnon 1997; Stuart *et al.* 2001). Additional monitoring programs have been established by the Barmah-Millewa Forum to survey waterbirds and land birds (R Webster pers. comm.) and frogs (Ward 2001, 2002).

The Atlas of Victorian Wildlife (NRE 2001) was consulted for recent and historical records of all species, examining all 5-minute grid cells that overlapped the forest.

Results

Mammals

A total of 26 species of native mammal and nine species of introduced mammal has been recorded in or near the forest in recent times (Appendix 1).

No exclusively terrestrial native small mammals occur in Barmah Forest. The Yellow-footed Antechinus is widespread, although uncommon, and spends time on the ground as well as being arboreal. This species was trapped in low numbers (14/1280 trap-nights on the early survey) and several were seen during the day foraging from branches of River Red Gums. The only other small mammal trapped on the early survey was the introduced House Mouse (5/1280 trap-nights). Even the normally common and widespread Echidna is rarely seen in Barmah Forest.

The two native aquatic mammals (Platypus and Water Rat) are present in the river and creeks, though only the latter is common.

Eastern Grey Kangaroos are common and conspicuous throughout the forest, with concentrations often occurring in and near extensive grass plains. White individuals are seen occasionally. The Black Wallaby has only recently been recorded within Barmah Forest with the first record on the Atlas of Victorian Wildlife from 1994. This species has recently expanded its range into western and northern Victoria (Menkhorst 1995). Common introduced ground-

dwelling mammals include European Rabbits (in fluctuating numbers, e.g. more in 1980 than 1977), Brown Hares, Red Fox, Feral Cat (mainly on forest margins), Feral Horse (several herds of 'brumbies', mainly in central and western parts of the forest) and Feral Pig (especially in swamps in the west of the forest). There have been recent records of Sambar Deer, perhaps illegally released, but it is not known if they have established a population.

Seven species of arboreal mammals inhabit Barmah Forest. Common Brushtail Possums are common among River Red Gums while Common Ringtail Possums occur on the box ridges. For example, during the 1991 survey Common Ringtail Possums were recorded at densities of 5-7 animals per ha at the two sites in box woodlands, while none was recorded at the three Red Gum sites. Sugar Gliders are scarce, and mainly found near riverbanks with Silver Wattles. This area is close to the inland edge of their range and Sugar Gliders appear to be uncommon compared to elsewhere in their distribution. Squirrel Gliders are also rare with only two records from the forest: two animals were observed on a Yellow Box rise on Long Plain Track in 1982 (J Alexander pers. comm.), and one was observed on Barmah Island in 1978. The semi-arboreal Brush-tailed Phascogale is also rarely recorded in the forest with only three records on the Atlas of Victorian Wildlife, all from the early 1980s. More recently, one individual was observed in 1991 on a mature Red Gum within semi-open Red Gum forest in the Barmah Lake day visitor area (PG O'Connor pers. comm.). The Feathertail Glider has been recorded only once from the forest (in 1999; L Conole pers. comm.). The small size and cryptic nature of this species makes it difficult to detect, and it is likely to occur more widely in the forest than this one record would suggest. Koalas have been re-introduced into the forest as part of a state-wide translocation program.

Bats comprise the largest proportion of the native mammal fauna of Barmah Forest, with one species of flying-fox and 12 species of insectivorous bats recorded (Appendix 1). Little Red Flying-foxes are irregular summer visitors, at times forming camps of ~200 in trees near Barmah Lake, drinking from nearby creeks (Loyn 1981) and feeding on River Red Gum blossom. The only camp regularly used by this species in Victoria is at the nearby town of Numurkah, where up to 2000 individuals congregate over summer.

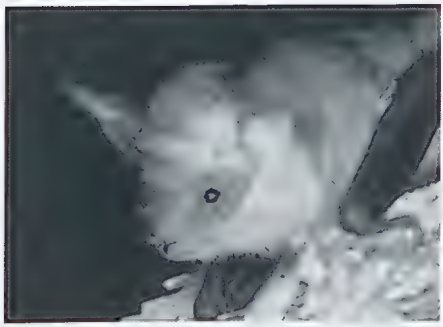

Fig. 2. The Gould's Lond-eared Bat *Nyctophilus gouldi* was recorded at considerably higher rates in Barmah Forest than elsewhere in the Northern Plains. Photo by Lindy Lumsden.

Barmah Forest has a high diversity of insectivorous bats with all but one species known from the Northern Plains occurring there. The one exception is the Greater Long-eared Bat *Nyctophilus timoriensis* (Fig. 2), which has been recorded from a single individual in Black Box woodland south-west of Echuca (Lumsden 1994). While most species occur in a range of vegetation types, the Southern Myotis is restricted to riparian forests, as it forages exclusively over water, catching aquatic insects and small fish (Menkhorst 1995). This species was caught on Barmah Island during the early surveys, and has been recorded in NSW along the Murray River at the Barmah Bridge (Law and Anderson 1999).

Capture rates of insectivorous bats during the 1990s surveys were higher in Barmah Forest than the mean for all the sites in the Northern Plains. Some species were recorded at markedly higher rates within Barmah, in particular the Gould's Long-eared Bat, which is close to the inland limit of its distribution in this area. The Southern Freetail Bat, Little Forest Bat and Gould's Wattled Bat also had high capture rates within Barmah. The Southern Forest Bat, which is common throughout much of Victoria, is rare in this region.

Table 1. Mean numbers of birds and bird guilds observed per 1-hour search of 4-ha study sites in Barmah Forest in a dry year (1977) and a wet year (1978). The first four sites were in mature River Red Gum forest; one was in River Red Gum burned by wildfire 10 years earlier and one was on a Grey Box ridge. Only the more common bird species are shown, but guild totals are based on all species in each guild. Abundance of old trees: few (1); many (3).

Species	Feeding guild	Nesting guild	Survey sites						Red Gum (mature)	Total '77	Total '78
			Gulf	Barmah Is	Top Is	Boals	Burnt	Box			
Abundance of old trees			3	1	2	3	1	2			
Grey Teal	W		1	0	0	3	0	0	1.0	0	8
Sacred Kingfisher	V	h	2.5	2	0.5	2	0	0	1.8	6	8
Sulphur-crested Cockatoo	S	h	4	0.5	0	0.5	0	0	1.3	6	4
Yellow Rosella	S	h	0	4	0	1	0	0	1.3	6	4
Red-rumped Parrot	S	h	0	0	0	0.5	0.5	2.5	0.1	0	7
Tree Martin	A	h	2	0.5	0	2.5	0.5	0	1.3	1	10
Grey Fantail	C		0	0	1	0	2.5	0	0.3	4	3
Willie Wagtail	OG		1.5	0	0	2	0	0	0.9	5	2
Jacky Winter	A		0	0	1	0	0	2.5	0.3	6	1
Rufous Whistler	C		0	0	1.5	0	5	1.5	0.4	6	10
Grey Shrike-thrush	G		1	2.5	0.5	3	0.5	1.5	1.8	8	10
Weebill	C		0	0	5.5	0	3	1.5	1.4	9	11
Striated Thornbill	C		0	0	3.5	0	4.5	0	0.9	5	11
Buff-rumped Thornbill	OG		0	0	5	0	1.5	0.5	1.3	6	8
White-browed Scrubwren	U		0	0	0	6.5	0	0	1.6	8	5
Superb Fairy-wren	OG		0.5	0	2.5	0.5	6	4.5	0.9	11	17
Dusky Woodswallow	A		1	2.5	0	2.5	0	0	1.5	8	4
Brown Treecreeper	B	h	3.5	2.5	0	11.5	0	5.5	4.4	19	27
White-throated Treecreeper	B	h	1.5	0	0	0.5	1	1.5	0.5	3	6
Striated Pardalote	C	h	8	0	4	5	5	3.5	4.3	24	27
White-plumed Honeyeater	N		13	26.5	2	11.5	0	6.5	13.3	72	47
All birds			42	47	31	58	36.5	43	44.5	250	265
Land birds			41	47	31	52.5	36.5	43	42.9	250	252
Land birds that nest in tree hollows			22	9.5	5	23.5	7	14.5	15.0	69	94
Hollow nesters as % land birds			54.1	20.9	16.0	43.3	19.2	33.7	33.6	27.6	37.3
Aerial insectivores	A Total		3	3	1.5	7	0.5	2.5	3.6	17	18
Bark-foraging insectivores	B Total		5	4	1	12	2	7	5.5	25	37
Canopy-foraging insectivores	C Total		8.5	1.5	16	5.5	21	8	7.9	51	70
Frugivores	F Total		0.5	0	0	0	1.5	0	0.1	3	1
Generalist insectivores	G Total		1	2.5	0.5	3	0.5	1.5	1.8	8	10
Nectarivores	N Total		13	28	2.5	11.5	1	8	13.8	77	51
Insectivores that forage from open ground	OG Total		2	0	8.5	3	9	7.5	3.4	25	35
Seed-eaters	S Total		4	4.5	0	2	0.5	3.5	2.6	14	15
Understorey insectivores	U Total		0	0	0	6.5	0	4.5	1.6	17	5
Carnivores (prey incl. vertebrates)	V Total		4	3.5	1	2	0.5	0.5	2.6	13	10
Water birds	W Total		1	0	0	5.5	0	0	1.6	0	13

Land birds

Overview of land bird community

Altogether 199 species of native land bird and six introduced species have been recorded in or near Barmah Forest (Appendix 2). Three species are numerically dominant in River Red Gum stands: White-plumed Honeyeater, Striated Pardalote and Brown Treecreeper, together forming 40% of individuals in the bird community (Table 1). Sulphur-crested Cockatoos are common and widespread, and make themselves conspicuous through their incessant screeching calls. Other parrots, including the yellow form of Crimson Rosella, are common and easily seen. Three black-and-white birds that have become common in farmland (Australian Magpie, Magpie-lark and Willie Wagtail) are widespread through the forest, especially in open grassy stands of River Red Gum. Emus are conspicuous, especially in and near grass plains and swamps. Hollow-nesting birds form a high proportion of the bird community, contributing means of 34% of individuals in mature stands of River Red Gum or Grey Box and up to 54% of individuals on some sites (Table 1).

Box ridges support a surprisingly similar fauna to the River Red Gum stands. White-plumed Honeyeaters are less dominant but still the most common honeyeater (Table 1). Some small insectivores are more common than in River Red Gum stands, including Yellow Thornbills and White-winged Trillers. A few common farmland birds favour box ridges, including Galahs and Yellow-rumped Thornbills (mainly in Yellow Box), though the latter species has apparently increased and is now common on treeless plains and among adjacent River Red Gums (L Conole pers. comm.). Hooded Robins are scarce inhabitants of box ridges, as are Gilbert's Whistlers and Striped Honeyeaters on the NSW side.

Many other species are localised, and some are associated with particular habitats such as box ridges or riverbanks (Appendix 2). Open-country species such as Richard's Pipits, Singing Bushlarks and Brown Songlarks are found only on treeless flood-plains, when conditions are suitable (e.g. after floods). Noisy Miners are found only in small patches of River Red Gum on edges of treeless plains, and in roadside trees outside the forest. White-browed Scrubwrens are found mainly in beds of rushes *Juncus* spp. in swamps, and locally elsewhere (e.g. on riverbanks and in fallen branches on logged coupes). Beds of Giant Rush are the main habitat for Little Grassbirds and support high densities of Superb Fairy-wrens, though the latter are common in a wide range of habitats. Red-browed Finches are locally common in thickets of Blackberry and other species along the riverbank. Other species are widespread but scarcer than in more varied forests outside the floodplain: they include two that forage from the bark of upper branches (Varied Sittella and Brown-headed Honeyeater) and a group of small insectivores such as Brown Thornbill and Striated Thornbill.

Several species are more common in roadside vegetation, farmland or forest patches outside the forest than in the forest itself, including Noisy Miner, Pied Butcherbird and Grey-crowned Babbler (Appendix 2). Bush Stone-curlews inhabit patches of remnant woodland outside the forest, and are rare within the forest. Gilbert's Whistlers and Striped Honeyeaters are resident in low numbers on box ridges on the NSW side (P Maher pers. comm.) but rare on the Victorian side. Speckled Warblers occur in a rarely grazed patch of shrubby River Red Gum forest near Nathalia, but apparently not in Barmah Forest. Chestnut-rumped Thornbills occur in a swamp dominated by Tangled Lignum *Muehlenbeckia florulenta* near Nathalia, and are rare in the forest where lignum is scarce. Several species characteristic of dry environments occur in small numbers outside the forest (Appendix 2).

Introduced land bird species

Four introduced bird species have been observed within the forest: Blackbird (in Blackberry thickets on riverbank, and nearby gardens); European Goldfinch (occasional birds, feeding mainly from introduced Asteraceae seeds but once reported taking nectar from box blossom; H Marshall pers. comm.), House Sparrow (groups locally around cattle yards) and Common Starling (breeding in tree hollows near Barmah Lake in spring; flocks sometimes feeding around drying lakes in summer). These and other species are more common in farmland and

towns outside the forest (Appendix 2), and a fifth species (Eurasian Tree Sparrow) occurs in small numbers at Nathalia. A sixth species, Common Myna, has recently reached Nathalia (2002), as part of its general range expansion, but has not been recorded in the forest.

Quantitative data from dry and wet years

Numbers of individuals of all species observed on the six study sites in a dry year and the following wet year are shown in Table 1, by species and grouped into guilds. Total numbers of land birds were remarkably similar in the two years. However, the most numerous species (White-plumed Honeyeater) was substantially more common in the dry year (1977), and species diversity was correspondingly higher in the wet year (1978).

Water birds were present on these sites in 1978, but not in 1977 (Table 1). Other guilds showed little difference between the two years, except for canopy foragers which were markedly more common in 1978 than 1977 (Table 1). This difference was highly significant ($p = 0.003$).

Total numbers of land birds were very similar between sites (Table 1) and differences were not significant ($p = 0.375$). However, substantial differences were evident for particular guilds (Table 1), including canopy foragers ($p < 0.001$), aerial foragers ($p = 0.046$), bark foragers ($p = 0.013$), hollow nesters ($p = 0.045$) and nectarivores ($p = 0.056$). Nectarivores were most numerous on Barmah Island in the west of the forest, and scarce in the recently burnt site and the dry site at Top Island. This guild was dominated by White-plumed Honeyeaters. Bark foragers (mainly treecreepers) were most numerous at Boals Deadwoods, which contained many large old River Red Gums (dead and alive) among low-lying swamp vegetation. Hollow-nesters were most numerous at Boals Deadwoods and Gulf, and least numerous at Barmah Island and the burnt site, where most old trees had been killed by silviculture and fire respectively. This guild included the treecreepers and a wide range of parrots and other species, but was dominated by Striated Pardalotes. Canopy foragers were most numerous at the recently burnt site and at Top Island, in the drier eastern part of the forest. The abundance of canopy foraging insectivores was negatively related to the abundance of White-plumed Honeyeaters across the sites and years ($r = -0.76$, $p < 0.001$, $n = 12$).

Water birds

When the forest floods, the treeless plains become lakes and are populated by vast flocks of water birds. During a major flood, the treed parts of the forest provide breeding habitat for hundreds of ducks, mainly of three common species (Grey Teal, Pacific Black Duck and Australian Wood Duck), most of which nest in hollow trees. The swamps attract a greater diversity of species, including Black Swans and a wide range of ducks, grebes and other birds. Flocks of Australian Pelicans may gather on treeless plains, though breeding has not been proved for that species.

The most spectacular breeding colonies are those of the communally breeding birds such as ibis and cormorants. In the major floods of 1973-75, it was reported that hundreds of thousands of ibis bred at several distinct colonies in the forest (Chesterfield *et al.* 1984). In subsequent years, hundreds or thousands of pairs have bred during spring floods, numbers varying with water depth. Beds of Giant Rush and sometimes Common Reed are the favoured habitat, and are typically flattened by the ibis to make nesting platforms. Straw-necked Ibis form dense colonies and Australian White Ibis generally form groups of smaller sub-colonies. Little Pied Cormorants nest colonially in River Red Gum trees, often in association with small numbers of Little Black Cormorants. Great Cormorants and Darters have nested locally in some years, selecting large River Red Gums near creeks. White-necked Herons regularly nest in small colonies, usually fewer than ten pairs, in tall River Red Gums. Yellow-billed Spoonbills sometimes nest singly in tall River Red Gums, or they may nest close to colonies of cormorants or White-necked Herons.

Great Egrets regularly nest in large River Red Gums on the New South Wales side of the river during spring floods. Previously they nested on the Victorian side at Black Swamp until 1964, and near-

by at Bullock Creek in 1966, 1968 and 1969 (Chesterfield *et al.* 1984). Small numbers of Little Egrets and Intermediate Egrets are sometimes seen with them, and both species have bred in the forest in the past (see Historical Changes below). Nankeen Night Herons also periodically nest on the NSW side of the river, with colonies of 2000-3000 nests having been recorded at Porters Plain during the flooding of 2000/01 (Webster 2001).

Most breeding occurs in spring, and winter floods rarely induce extensive breeding in the forest. In contrast, winter rains may induce flooding in nearby pasture, and floodwaters sometimes attract substantial numbers of waterbirds including some that rarely visit the forest itself, e.g. Red-necked Avocet. Many ducks and other waterbirds have bred on these floodwaters.

When floods recede from the forest, open muddy shores can attract small waders including Palaearctic migratory species such as Latham's Snipe and Common Greenshank. However, there is usually too much vegetation to provide good habitat for most migratory species, and numbers observed are generally low.

Reptiles

Twenty species of reptile have been recorded in Barmah Forest incuding two tortoises, two geckoes, six skinks, three other lizards and seven species of snakes (Appendix 3). Yellow-bellied Water Skinks are conspicuous among River Red Gums, and Boulenger's Skinks are common on box ridges (P Brown pers. comm.). Tortoise nests are often raided by Red Foxes, with eggshells and footprints remaining as evidence.

Historical records up until the 1970s listed snakes in the Barmah Forest as being very common (as per review by Leslie 1995). However, numbers have greatly decreased since this time, to the point where snakes are now uncommon. The Red-bellied Black Snake is the most commonly observed snake in Barmah Forest today, though Eastern Tiger Snakes may have once been more common (Leslie 1995). Eastern Brown Snakes are also occasionally seen, along with some rarer and more cryptic species (Appendix 3). Carpet Pythons favour the drier Box ridges.

Frogs

Ten species from two families of amphibians have been confirmed to reside in or near Barmah Forest (Appendix 4). Hylidae is represented only by Peron's Tree Frog, while Leptodactylidae is represented by the Southern Bullfrog, Barking Marsh Frog, Spotted Marsh Frog, Giant Bullfrog, Common Spadefoot Toad, Bibron's Toadlet, Plains Froglet, Common Froglet and Sloane's Froglet.

Common Spadefoot Toad and Bibron's Toadlet are recent new records for the forest, extending the known range of the latter species. There is a single record of the critically endangered Giant Bullfrog from the farmland area just south of Barmah Forest. A species formerly listed as occurring in Barmah Forest, the Warty Bell Frog *Litoria raniformis*, was not found to occur in the forest and the single original record was found to be erroneous (P Robertson pers. comm.).

Well vegetated, shallowly-flooded wetlands have been found to contain the highest numbers of vocalising and breeding frogs. However, ephemeral rain-filled depressions were also found to be significant, and the two new species records for the forest came from such locations. Creeks and rivers generally support the lowest numbers of frogs (Ward 2001, 2002).

Fish

Twenty-eight species of fish have been recorded in the vicinity of Barmah Forest, with ten of these being exotic (Appendix 5).

Native fish, particularly large 'commercial' species such as Murray Cod and Golden Perch, were known to be particularly plentiful in the mid-1800s to the early 1900s when commercial fishing was undertaken in the Murray River and adjoining Barmah-Moira Lakes. However, significant decreases in catches were recorded by the 1890s, and Golden Perch replaced Murray Cod as the most common species (Ross 1892, cited in Leslie 1995).

Carp and Redfin were introduced to lagoons in the Deniliquin district in 1884 and goldfish were in fountains in Echuca in the 1890s (Leslie 1995). Even without deliberate release into the adjoining waterways, floodwaters would cause an inevitable introduction into the river system.

By 1993, a fish study in Moira Lake failed to locate a single 'commercial' species of fish (Gerkhe and Brown, cited in Leslie 1995). Instead, Carp dominated the waterways. Although other studies have found populations of Murray Cod, Golden Perch and Silver Perch to persist in Barmah Forest, some native species have declined so much that they are now rarely encountered in the area (McKinnon 1997; Sivakumaran and Brown 2001). Such species include River Blackfish, Freshwater Catfish and Macquarie Perch. Furthermore, Carp have been found to spawn so prolifically in the shallow vegetated wetlands within Barmah Forest that the region may be a major point source breeding location within the Murray system (Stuart *et al.* 2001).

Threatened Species

Of the mammal species recorded in Barmah Forest, three are listed as threatened (Appendix 1). Within Victoria the endangered Squirrel Glider is found only in the Northern Plains and adjacent Box-Ironbark region. It occurs in either box woodlands with more than one species of eucalypt, or in River Red Gum forests with an understorey of wattles (Menkhorst *et al.* 1988). Areas that contain a number of tree species appear important to provide food resources throughout the year. Two of the three sightings within Barmah Forest have been in mature Yellow Box woodlands.

The Brush-tailed Phascogale is listed as vulnerable in Victoria with its core distribution through the box-ironbark forests inland of the Divide (Menkhorst 1995). There are few observations from Red Gum forests. Further information is required on this species to ascertain its status and distribution within Barmah Forest.

Nine land bird species listed as endangered in Victoria (NRE 2000) have been observed in or near Barmah Forest (Appendix 2), but most appear to be vagrants or rare visitors to the general area. Three threatened species may have important habitats within the forest: Barking Owl, Superb Parrot and Grey-crowned Babbler. The forest is one of the few breeding habitats for Superb Parrots in the State (Chesterfield *et al.* 1984; Webster 1988; Garnett and Crowley 2000). Barking Owls have been recorded on few occasions, and are likely to be resident in small numbers. Grey-crowned Babblers have declined within the forest and are now more often seen at, roadsides outside the forest (Chesterfield *et al.* 1984; Robinson 1994; Garnett and Crowley 2000). A small group persisted on Top Island until at least 1979 (Chesterfield *et al.* 1984).

Several waterbird species are currently listed as threatened (NRE 2000) on the basis of restricted breeding colonies. This approach is currently being revised. Barmah Forest is sometimes one of the few breeding colonies in the State for Great Egrets, and has been of even greater importance for other species of egret (see Historical Changes, below). The forest may sometimes be an important breeding habitat for two threatened and poorly known non-colonial waterbirds with cryptic habits. Australasian Bitterns inhabit beds of Giant Rush, and several may be heard booming in the forest during floods (Chesterfield *et al.* 1984). Little Bitterns prefer beds of Cumbungi or Common Reed, and may be found on Top Island and Boals Deadwoods during floods, as well as beside farm dams outside the forest. Two or three pairs of White-bellied Sea Eagles breed in the forest.

Two reptile species (Carpet Python and Woodland Blind Snake), one amphibian (Giant Bullfrog) and six fish species (Silver Perch, Trout Cod, Murray Cod, Golden Perch, Macquarie Perch and Freshwater Catfish), are listed as threatened in Victoria (Appendices 3-5). As discussed above, some of the fish are now rare or absent and the Giant Bullfrog is known only from just outside the forest.

Discussion

There is currently a very low diversity and abundance of terrestrial mammals in Barmah Forest. This may be a natural occurrence, as the pattern of regular flooding would result in inhospitable conditions unless species were able to climb trees or find high points on which to escape. In areas where there are alternative vegetation types on higher ground (e.g. Black Box woodlands around the edge of the forest, Yellow Box woodlands on sandy rises) these may be important refuges for individuals to shift into to escape the inunda-

tion. Where clearing has extended right up to the edge of the Red Gum, this may limit the options for small mammals and hence influence their survival. The low diversity may also be a result of management changes since European settlement. There is evidence to suggest that other species of terrestrial mammals once occurred in this region (see below). Grazing and trampling by domestic and feral animals may have reduced the quality of habitat for these species, and increased predation from introduced predators may also have contributed to their demise.

In most areas of Victoria, native rodents are usually a prominent component of the small mammal fauna (Menkhorst 1995). However, in Barmah Forest the semi-aquatic Water Rat is the only species of native rodent present. It is likely that several other species of rodents once occurred in the Northern Plains, but are now extinct (see Historical Changes, below).

Compared to the Grey Box woodlands of the Northern Plains, the Red Gum forests have higher densities of Common Brushtail Possums, but lower densities of Common Ringtail Possums. All the arboreal and semi-arboreal mammals found in the region require tree hollows in which to nest and are more abundant in areas with higher densities of large old trees with hollows.

The extensive area of Red Gum woodland in Barmah Forest provides important habitat for bats within the region. Recent studies of the roosting and foraging requirements of the Lesser Long-eared Bat and Gould's Wattled Bat found that individuals fed in remnant vegetation within the rural landscape, but roosted within Barmah Forest (Lumsden *et al.* 2002). Both species were highly selective of the types of trees in which they roosted, with Gould's Wattled Bats selecting very large live River Red Gums (Lumsden *et al.* in press). In contrast Lesser Long-eared Bats roosted predominantly in dead trees, and the females selected large old ring-barked Red Gums as maternity sites to raise their young. Entrances were usually narrow fissures which provided protection from predators and competitors. Individuals regularly shifted roost sites with subsequent roosts close together. This behavioural pattern requires a high density of suitable roost sites within a small area to support a colony of bats (Lumsden and Bennett 2000). Although the proportion of large trees is lower in Barmah Forest than in remnants within farmland due to timber harvesting (Bennett *et al.* 1994), the area of forest is much larger and hence there are more suitable roost sites overall. Both species selected areas of the forest that had high densities of their preferred roost trees (Lumsden *et al.* 2002).

As a habitat for land birds, the stands of River Red Gum appear to be quite similar to less extensive stands elsewhere along the Murray River. Birds that nest in tree hollows are substantially more common than in other forest types (Loyn 1985), reflecting the age of many of the veteran trees and their tendency to form hollows through dropping branches. Ground-feeding birds respond positively to the amount of coarse woody debris (Mac Nally *et al.* 2001). Birds that feed from open ground are common if they can use alternative substrates during floods (e.g. Brown Treecreeper and Buff-rumped Thornbills feeding from bark, and Superb Fairy-wrens among aquatic plants), while obligate ground feeders are scarce or confined to box ridges (Chesterfield *et al.* 1984; Loyn 1985). This is analogous to the current situation with small native mammals, of which the only remaining species (Yellow-footed Antechinus, discussed above) can forage both from the ground and trees. Perhaps the deduced loss of mammal species from Barmah Forest owes more to clearing of adjacent box woodlands, than to changes within the forest itself.

White-plumed Honeyeaters dominate the bird fauna of the River Red Gum stands, and appear to exclude small insectivores through territorial aggression. This may account for the patchy distribution of small insectivores such as thornbills in the forest. The typical honeyeaters of box-ironbark forests are Fuscous Honeyeaters *Lichenostomus fuscus* and Yellow-tufted Honeyeaters *L. melanops* (Loyn 1985; Silveira *et al.* 1997), but they are absent from box ridges in Barmah Forest, perhaps because White-plumed Honeyeaters are so prevalent. Recent data from a large group of study sites among the River Red Gums in the forest (Mac Nally *et al.* 2001) include White-plumed Honeyeater as the fifth most common species (not the

first as in earlier work), and two small insectivores (Weebill and Yellow-rumped Thornbill) featured in the top four. This may suggest a recent change in the dominance of White-plumed Honeyeaters and supports the notion of an inverse relationship between numbers of small insectivores and White-plumed Honeyeaters.

Historical changes

One of the earliest European settlers in the Northern Plains was Edward Curr who occupied a pastoral run near the junction of the Murray and Goulburn Rivers in the 1840s (Curr 1883). He described the aboriginal women digging out rats for food and referred to 'kangaroo-rats' and 'field-rats'. Unfortunately, as no specimens were collected we cannot determine which species these may have been. The Lesser Stick-nest Rat *Leporillus apicalis*, a native rodent that builds large nests of sticks, was recorded in the Mallee region of Victoria in 1857 (Wakefield 1966) and may also have been in this area. It is interesting to speculate whether 'Rat Castle Creek' in Barmah Forest was named after this species. Several species of small macropods have disappeared from the Northern Plains. The Rufous Bettong *Aepyprymnus rufescens* and Bridled Nailtail Wallaby *Onychogalea fraenata* were recorded from Red Gum forests, downstream of Barmah (near Gunbower) in the 1850s (Wakefield 1966) and may also have been present in Barmah Forest. Both these species are now extinct in Victoria (Menkhorst 1995).

Among land birds, both Bell Miners and Crested Bellbirds were reported at Barmah Forest in the 19th century (Curr 1883; Blakers *et al.* 1984; Chesterfield *et al.* 1984) and no longer occur in the region. Several honeyeaters occur erratically in or near the forest, and Blue-faced Honeyeaters may have declined through persecution by fruit growers. White-throated Treecreepers were apparently rare before the 1940s and are now common, perhaps because of increases in stand density with regeneration after logging (Chesterfield *et al.* 1984). Pied Currawongs have increased over the same period, as winter visitors mainly to the forest edge. Long-billed Corellas increased during the 1970s. Recent data (Mac Nally *et al.* 2001) and Atlas records (Appendix 2) suggest that Yellow-rumped Thornbills have increased since the 1970s and early 1980s when they were scarce in the forest (Chesterfield *et al.* 1984). Restless Flycatchers may have declined and only two were observed during recent studies (L Conole pers. comm.). Many other changes may have occurred, but gone unnoticed or undocumented.

Changes in populations of water birds may be readily noticed by visiting naturalists, but hard to interpret because of the mobility of these birds, and the great variations expected from year to year with different flood patterns. Magpie Geese were common in the 19th century (Chesterfield *et al.* 1984) and disappeared from Victoria until recent reintroductions. Brolgas were also common in the 1890s (Leslie 1995). Hundreds of Brolgas displayed and nested on War Plain in the 1920s (Tom Galloway in Chesterfield *et al.* 1984), and the species is now much reduced, with a pair nesting in nearby farmland but rarely visiting the forest. A great diversity of breeding waterbirds was recorded by Norman Favoloro in the 1930s (in Chesterfield *et al.* 1984), including Whiskered Terns, Hoary-headed Grebes and Baillon's Crakes. Verbal records from various sources suggest that Intermediate Egrets were the most numerous egret breeding in the forest before the 1940s (Chesterfield *et al.* 1984), and they are now the rarest. Hundreds of egrets bred at Black Swamp during floods at the time, whereas now breeding is more common at Algeboia Plains on the NSW side, and involves greatly reduced numbers, mainly of Great Egrets. Ibis now breed in lower numbers than they did in the peak floods of the early 1970s. Plumed Whistling-Ducks and Cattle Egrets colonised the region in the early 1970s, but are found mainly in surrounding farmland.

Azure Kingfishers became temporarily scarce in the late 1970s, perhaps because of the proliferation of European Carp and consequent turbidity in many creeks (Chesterfield *et al.* 1984). However, they recovered quickly and were again a common feature of the river and creeks in the 1980s.

Many factors have been implicated in the decline of frogs, reptiles and fish. These include commercial fishing pressures, competition and predation from introduced

species (e.g. fox predation on tortoise eggs or Mosquitofish predation on frog eggs and larvae), structural alterations to habitat (through grazing pressure and altered flow regimes), reduction of instream habitat (such as through extensive de-snagging operations), and altered flooding regimes (commensurate with river regulation in the mid-1930s).

Changes in habitat have occurred, especially on the swamps, through combined effects of river regulation and grazing. Trees are encroaching on some previously open plains and dying back on others (Chesterfield 1986). Beds of Giant Rush have tended to increase at the expense of Cumbungi or Common Reed, which are more palatable to cattle (Chesterfield 1986).

Management

Deep spring floods clearly provide breeding conditions for waterbirds, and their frequency and extent have declined with river regulation. It will be a special challenge to provide adequate flows with increasing demands for water use in the Murray Darling catchment (MDBC 2000). Flood patterns are important for all aspects of the forest's ecology, including vegetation (Bren and Gibbs 1986; Chesterfield 1986; Ward 1991, 1994; Blanch *et al.* 1999), health of trees (Dexter *et al.* 1986), fish (McKinnon 1997; Gehrke and Harris 2001), and waterbirds (Leslie 2001). A specific allocation of environmental water has been provided for the Barmah-Millewa forest from the regulated river system, and is primarily used to allow waterbirds (and flora and other fauna when known to be necessary) to complete breeding attempts (Leslie and Ward in press).

Old hollow-bearing trees are locally conspicuous, especially along the river (Newton-John 1992), although they occur at lower densities in the forest compared to many remnants in farmland (Bennett *et al.* 1994). Logging and firewood collection have been reduced in recent years, and this should facilitate efforts to maintain the supply of hollows and replenish coarse woody debris at sustainable rates. Grazing has contributed to major changes in wetland vegetation (Chesterfield 1986), and planned reductions in grazing should help reverse some of those changes, with benefits to certain water birds and land birds. The ecosystem is highly complex, and a system of regular monitoring and adaptive management is needed to deal with the unexpected changes that can confidently be expected in future.

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Appendix 1. Mammals of Barmah Forest, including the number of records on the Atlas of Victorian Wildlife. Note that numbers of Atlas records may give a false impression of the abundance of species subject to special survey effort (e.g. Koalas), while introduced species tend to be under-recorded. + indicates personal communication. Threatened species categories: End, endangered; Vul, vulnerable; LRnt, lower risk, near threatened (NRE 2000). I, introduced to Australia.

Common name	Scientific name	Atlas records in or near Barmah Forest	Threatened status in Victoria
Short-beaked Echidna	*Tachyglossus aculeatus*	1	
Platypus	*Ornithorhynchus anatinus*	3	
Yellow-footed Antechinus	*Antechinus flavipes*	20	
Brush-tailed Phascogale	*Phascogale tapoatafa*	3	Vul
Common Brushtail Possum	*Trichosurus vulpecula*	32	
Feathertail Glider	*Acrobates pygmaeus*	+	
Sugar Glider	*Petaurus breviceps*	4	
Squirrel Glider	*Petaurus norfolcensis*	3	End
Common Ringtail Possum	*Pseudocheirus peregrinus*	10	
Eastern Grey Kangaroo	*Macropus giganteus*	55	
Black Wallaby	*Wallabia bicolor*	2	
Koala	*Phascolarctos cinereus*	79	
Little Red Flying-fox	*Pteropus scapulatus*	1	
Southern Freetail Bat	*Mormopterus* sp.	37	
Eastern Freetail Bat	*Mormopterus* sp.	4	
White-striped Freetail Bat	*Tadarida australis*	49	
Gould's Wattled Bat	*Chalinolobus gouldii*	47	
Chocolate Wattled Bat	*Chalinolobus morio*	91	
Southern Myotis	*Myotis macropus*	2	LRnt
Lesser Long-eared Bat	*Nyctophilus geoffroyi*	71	
Gould's Long-eared Bat	*Nyctophilus gouldi*	27	
Inland Broad-nosed Bat	*Scotorepens balstoni*	18	
Large Forest Bat	*Vespadelus darlingtoni*	25	
Southern Forest Bat	*Vespadelus regulus*	6	
Little Forest Bat	*Vespadelus vulturnus*	99	
Water Rat	*Hydromys chrysogater*	11	
House Mouse	*Mus musculus*	14	I
Black Rat	*Rattus rattus*	1	I
Red Fox	*Vulpes vulpes*	13	I
Cat (feral)	*Felis catus*	1	I
Horse (feral)	*Equus caballus*	11	I
Sambar Deer	*Cervus unicolor*	+	I
Pig (feral)	*Sus scrofa*	2	I
Brown Hare	*Lepus capensis*	8	I
European Rabbit	*Oryctolagus cuniculus*	14	I

Appendix 2. Birds of Barmah Forest. Note that records from imprecisely defined locations do not generally appear as 5-minute Atlas records and are marked +: this applies mainly to records before the 1990s. AR, Atlas records in or near Barmah Forest; BLHab, broad local habitats; FLHab, finer local habitats; MS, migratory status; TSVic, threatened status in Victoria. *Broad and fine habitats:* W, water bird (v, among dense vegetation; m, mainly on bare mudflats; sv, in lightly vegetated swamps; o, in open water; t, nesting in or among trees; s, nesting colonially in swamps when flooded; r, along river; f, mainly in farmland or farm dams outside forest). F, forest or woodland bird (rg, mainly in red gum; b, mainly in box; s, most common in or near swamps or riverbanks; p, most common on treeless plains within the forest; rd, more common along roadsides or in remnant vegetation outside the forest; g, more common in gardens outside the forest; no symbol, widespread). O, open country species, usually found outside the forest (gp, mainly near gravel pits). *Migratory or other temporal status:* S, mainly summer visitor (e.g. Sept-April); W, mainly winter visitor (March-Sept); V, vagrant or rare visitor; X, extinct, not recorded since 19th century. *Threatened or introduced status:* CrEn, critically endangered; End, endangered; Vul, vulnerable; LRnt, lower risk, near threatened; DD, data deficient; I, introduced to Australia. *, reeds or cumbungi; †, rushes.

Common Name	Scientific Name	AR	BLHab	FLhab	MS	TSVic
Emu	*Dromaius novaehollandiae*	44	F	s		
Stubble Quail	*Coturnix pectoralis*	4	O			
Brown Quail	*Coturnix ypsilophora*	3	F	s		DD
Painted Button-quail	*Turnix varia*	15	F			
Peaceful Dove	*Geopelia striata*	84	F	rg		
Diamond Dove	*Geopelia cuneata*	2	F	rg	V	Vul
Common Bronzewing	*Phaps chalcoptera*	27	F	b		
Crested Pigeon	*Ocyphaps lophotes*	42	O			
Buff-banded Rail	*Gallirallus philippensis*	4	W	v		
Spotless Crake	*Porzana tabuensis*	1	W	v		
Australian Spotted Crake	*Porzana fluminea*	+	W	v		
Baillon's Crake	*Porzana pusilla*	+	W	v	S	
Black-tailed Native-hen	*Gallinula ventralis*	2	W	v		
Dusky Moorhen	*Gallinula tenebrosa*	14	W	r		
Purple Swamphen	*Porphyrio porphyrio*	16	W	v		
Eurasian Coot	*Fulica atra*	5	W	o		
Bush Stone-curlew	*Burhinus grallarius*	+	F	rd		
Great Crested Grebe	*Podiceps cristatus*	4	W	o		
Australasian Grebe	*Tachybaptus novaehollandiae*	6	W	o		
Hoary-headed Grebe	*Poliocephalus poliocephalus*	1	W	o		
Great Cormorant	*Phalacrocorax carbo*	52	W	t		
Little Black Cormorant	*Phalacrocorax sulcirostris*	44	W	t		
Pied Cormorant	*Phalacrocorax varius*	8	W	o		LRnt
Little Pied Cormorant	*Phalacrocorax melanoleucos*	80	W	t		
Darter	*Anhinga melanogaster*	21	W	r,t		
Australian Pelican	*Pelecanus conspicillatus*	37	W			
Whiskered Tern	*Chlidonias hybridus*	8	W	sv	S	LRnt
Silver Gull	*Larus novaehollandiae*	5	W	o		
Black-winged Stilt	*Himantopus himantopus*	+	W	sv		
Red-necked Avocet	*Recurvirostra novaehollandiae*	+	W	sv/o/f		
Red-kneed Dotterel	*Erythrogonys cinctus*	1	W	sv		
Masked Lapwing	*Vanellus miles*	39	W,O	m		
Banded Lapwing	*Vanellus tricolor*	1	O			
Red-capped Plover	*Charadrius ruficapillus*	+	W	m		
Black-fronted Dotterel	*Elseyornis melanops*	15	W	m		
Common Greenshank	*Tringa nebularia*	1	W	m	S	
Sharp-tailed Sandpiper	*Calidris acuminata*	+	W	sv	S	
Red-necked Stint	*Calidris ruficollis*	1	W	m	S	
Latham's Snipe	*Gallinago hardwickii*	3	W	v	S	
Brolga	*Grus rubicunda*	2	W	f		Vul
Glossy Ibis	*Plegadis falcinellus*	1	W	sv		Vul
Australian White Ibis	*Threskiornis molucca*	85	W	s		
Straw-necked Ibis	*Threskiornis spinicollis*	63	W	s		
Royal Spoonbill	*Platalea regia*	24	W	t		Vul
Yellow-billed Spoonbill	*Platalea flavipes*	44	W	t		
Little Egret	*Egretta garzetta*	4	W	t		CrEn
Intermediate Egret	*Ardea intermedia*	21	W	t, sv		CrEn

Common Name	Scientific Name	AR	BLHab	FLhab	MS	TSVic
Great Egret	*Ardea alba*	59	W	t		End
Cattle Egret	*Ardea ibis*	+	W,O	t	V	
White-faced Heron	*Egretta novaehollandiae*	90	W	t		
White-necked Heron	*Ardea pacifica*	52	W	t		
Nankeen Night Heron	*Nycticorax caledonicus*	31	W	t		Vul
Little Bittern	*Ixobrychus minutus*	3	W	v*	S	End
Australasian Bittern	*Botaurus poiciloptilus*	5	W	v†		End
Australian Wood Duck	*Chenonetta jubata*	70	W	t		
[Magpie Goose]	*Anseranus semipalmata*	+	W		X	End
Black Swan	*Cygnus atratus*	42	W	o		
Plumed Whistling-Duck	*Dendrocygna eytoni*	2	W	f		
Australian Shelduck	*Tadorna tadornoides*	22	W			
Pacific Black Duck	*Anas superciliosa*	71	W	t		
Chestnut Teal	*Anas castanea*	1	W	t		
Grey Teal	*Anas gracilis*	59	W	t		
Australasian Shoveler	*Anas rhynchotis*	2	W	o		Vul
Pink-eared Duck	*Malacorhynchus membranaceus*	3	W	t		
Freckled Duck	*Stictonetta naevosa*	+	W			End
Hardhead	*Aythya australis*	3	W	o		Vul
Blue-billed Duck	*Oxyura australis*	1	W	o		Vul
Musk Duck	*Biziura lobata*	7	W	o		Vul
Spotted Harrier	*Circus assimilis*	2	O			
Swamp Harrier	*Circus approximans*	20	W	v		
Brown Goshawk	*Accipiter fasciatus*	11	F			
Collared Sparrowhawk	*Accipiter cirrhocephalus*	6	F			
Wedge-tailed Eagle	*Aquila audax*	42	F			
Little Eagle	*Hieraaetus morphnoides*	7	F			
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	15	W	t		End
Whistling Kite	*Haliastur sphenurus*	50	W	t		
Black Kite	*Milvus migrans*	3	O			
Black-shouldered Kite	*Elanus axillaris*	7	O			
Grey Falcon	*Falco hypoleucos*	+	F	rd	V	
Australian Hobby	*Falco longipennis*	11	F,O			
Peregrine Falcon	*Falco peregrinus*	6	F	rg		
Black Falcon	*Falco subniger*	2	O			End
Brown Falcon	*Falco berigora*	29	O			
Nankeen Kestrel	*Falco cenchroides*	18	O			
Southern Boobook	*Ninox novaeseelandiae*	19	F			
Barking Owl	*Ninox connivens*	2	F			End
Barn Owl	*Tyto alba*	12	O			
Musk Lorikeet	*Glossopsitta concinna*	2	F	b		
Sulphur-crested Cockatoo	*Cacatua galerita*	336	F,O	rg		
Major Mitchell's Cockatoo	*Cacatua leadbeateri*	1	F		V	Vul
Little Corella	*Cacatua sanguinea*	8	O			
Long-billed Corella	*Cacatua tenuirostris*	44	F,O	rg		
Galah	*Cacatua roseicapilla*	332	O			
Cockatiel	*Nymphicus hollandicus*	9	O			
Superb Parrot	*Polytelis swainsonii*	195	F			End
Crimson (Yellow) Rosella	*Platycercus elegans flaveolus*	301	F	rg		
Eastern Rosella	*Platycercus eximius*	70	F,O	b		
Red-rumped Parrot	*Psephotus haematonotus*	196	F,O			
Blue Bonnet	*Northiella haematogaster*	1	F,O		V	
Budgerigar	*Melopsittacus undulatus*	2	F,O		V	
Tawny Frogmouth	*Podargus strigoides*	12	F			
Australian Owlet-nightjar	*Aegotheles cristatus*	4	F			
Dollarbird	*Eurystomus orientalis*	7	F	rg, f	S	
Azure Kingfisher	*Alcedo azurea*	24	W	r		
Laughing Kookaburra	*Dacelo novaeguineae*	183	F			
Sacred Kingfisher	*Todiramphus sanctus*	190	F		S	
Red-backed Kingfisher	*Todiramphus pyrrhopygia*	+	F	gp	V	
Rainbow Bee-eater	*Merops ornatus*	49	F		S	
White-throated Needletail	*Hirundapus caudacutus*	2	F,O		S	

Common Name	Scientific Name	AR	BLHab	FLhab	MS	TSVic
Fork-tailed Swift	*Apus pacificus*	1	F,O		S	
Pallid Cuckoo	*Cuculus pallidus*	19	F		S	
Fan-tailed Cuckoo	*Cacomantis flabelliformis*	16	F		S	
Horsfield's Bronze-Cuckoo	*Chrysococcyx basalis*	22	F		S	
Shining Bronze-Cuckoo	*Chrysococcyx lucidus*	11	F		S	
Black-eared Cuckoo	*Chrysococcyx osculans*	+	F		S	
Welcome Swallow	*Hirundo neoxena*	132	O,W			
White-backed Swallow	*Cheramoeca leucosternus*	2	O	gp		
Tree Martin	*Hirundo nigricans*	47	F	rg	S	
Fairy Martin	*Hirundo ariel*	6	O,W	r	S	
Grey Fantail	*Rhipidura fuliginosa*	164	F			
Rufous Fantail	*Rhipidura rufifrons*	1	F		SV	
Willie Wagtail	*Rhipidura leucophrys*	220	F,O	rg		
Leaden Flycatcher	*Myiagra rubecula*	9	F	rg	S	
Restless Flycatcher	*Myiagra inquieta*	58	F			
Jacky Winter	*Microeca fascinans*	168	F			
Scarlet Robin	*Petroica multicolor*	29	F			
Red-capped Robin	*Petroica goodenovii*	73	F			
Flame Robin	*Petroica phoenicea*	22	F,O	p	W	
Pink Robin	*Petroica rodinogaster*	+	F		WV	
Hooded Robin	*Melanodryas cucullata*	4	F	b		
Golden Whistler	*Pachycephala pectoralis*	29	F		W	
Rufous Whistler	*Pachycephala rufiventris*	155	F		S	
Gilbert's Whistler	*Pachycephala inornata*	5	F	b		
Grey Shrike-thrush	*Colluricincla harmonica*	283	F			
Magpie-lark	*Grallina cyanoleuca*	112	F,O	rg		
Crested Shrike-tit	*Falcunculus frontatus*	91	F			
[Crested Bellbird]	*Oreoica gutturalis*	+	F		X	
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	141	F			
White-bellied Cuckoo-shrike	*Coracina papuensis*	2	F			
Ground Cuckoo-shrike	*Coracina maxima*	+	O	p	V	
White-winged Triller	*Lalage sueurii*	29	F		S	
Grey-crowned Babbler	*Pomatostomus temporalis*	16	F	rg, rd		End
White-browed Babbler	*Pomatostomus superciliosus*	3	F	b		
White-fronted Chat	*Epthianura albifrons*	3	O,W	p		
Crimson Chat	*Ephthianura tricolor*	+	O	p	SV	
Southern Whiteface	*Aphelocephala leucopsis*	+	O	edge		
Speckled Warbler	*Cthonicola sagittata*	+	F	rd		
Western Gerygone	*Gerygone fusca*	60	F		S	
Weebill	*Smicrornis brevirostris*	202	F			
Striated Thornbill	*Acanthiza lineata*	53	F			
Yellow Thornbill	*Acanthiza nana*	61	F	b, g		
Brown Thornbill	*Acanthiza pusilla*	7	F	s		
Buff-rumped Thornbill	*Acanthiza reguloides*	169	F			
Chestnut-rumped Thornbill	*Acanthiza uropygialis*	+	F	lignum		
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	121	O	g		
White-browed Scrubwren	*Sericornis frontalis*	32	F	s		
Brown Songlark	*Cincloramphus cruralis*	7	O		S	
Rufous Songlark	*Cincloramphus mathewsi*	35	F	rg	S	
Little Grassbird	*Megalurus gramineus*	7	W	v		
Clamorous Reed Warbler	*Acrocephalus stentoreus*	28	W	v	S	
Superb Fairy-wren	*Malurus cyaneus*	195	F	s		
White-breasted Woodswallow	*Artamus leucorynchus*	35	F,W	rg	S	
Masked Woodswallow	*Artamus personatus*	1	F		S	
White-browed Woodswallow	*Artamus superciliosus*	28	F		S	
Black-faced Woodswallow	*Artamus cinereus*	1	O			
Dusky Woodswallow	*Artamus cyanopterus*	139	F		S	
Varied Sittella	*Daphoenositta chrysoptera*	36	F			
Brown Treecreeper	*Climacteris picumnus*	362	F			
White-throated Treecreeper	*Cormobates leucophaeus*	299	F			
Mistletoebird	*Dicaeum hirundinaceum*	92	F			
Spotted Pardalote	*Pardalotus punctatus*	41	F		W	
Striated Pardalote	*Pardalotus striatus*	347	F			

Common Name	Scientific Name	AR	BLHab	FLhab	MS	TSVic
Silvereye	*Zosterops lateralis*	26	F	g		
White-naped Honeyeater	*Melithreptus lunatus*	1	F		WV	
Black-chinned Honeyeater	*Melithreptus gularis*	32	F			
Brown-headed Honeyeater	*Melithreptus brevirostris*	43	F			
Painted Honeyeater	*Grantiella picta*	2	F	b	SV	Vul
White-plumed Honeyeater	*Lichenostomus penicillatus*	328	F			
[Bell Miner]	*Manorina melanophrys*	1	F		X	
Noisy Miner	*Manorina melanocephala*	56	F	rd		
Red Wattlebird	*Anthochaera carunculata*	3	F		V	
Striped Honeyeater	*Plectorhyncha lanceolata*	+	F	b, NSW		
Regent Honeyeater	*Xanthomyza phrygia*	+	F		V	
Blue-faced Honeyeater	*Entomyzon cyanotis*	3	F			
Noisy Friarbird	*Philemon corniculatus*	153	F		S	
Little Friarbird	*Philemon citreogularis*	144	F	rg	S	
Richard's Pipit	*Anthus novaeseelandiae*	21	O	p		
Singing Bushlark	*Mirafra javanica*	2	O	p	S	
Diamond Firetail	*Stagonopleura guttata*	26	F	b		
Zebra Finch	*Taeniopygia guttata*	11	O			
Red-browed Finch	*Neochmia temporalis*	15	F	s		
Olive-backed Oriole	*Oriolus sagittatus*	17	F	rg	S	
White-winged Chough	*Corcorax melanorhamphos*	115	F			
Pied Currawong	*Strepera graculina*	25	F		W	
Pied Butcherbird	*Cracticus nigrogularis*	14	F	rd		
Grey Butcherbird	*Cracticus torquatus*	2	F	rd		
Australian Magpie	*Gymnorhina tibicen*	259	F,O	rg		
Australian Raven	*Corvus coronoides*	269	F			
Little Raven	*Corvus mellori*	22	O			
Common Blackbird	*Turdus merula*	10	F	g		I
House Sparrow	*Passer domesticus*	21	O	g		I
Eurasian Tree Sparrow	*Passer montanus*	+	O	g, Nathalia		I
European Goldfinch	*Carduelis carduelis*	10	O	g		I
Common Starling	*Sturnus vulgaris*	67	O,W			I
Common Myna	*Acridotheres tristis*	+	O	g, Nathalia		I

Appendix 3. Reptiles of Barmah Forest. Threatened species categories: End, endangered; Vul, vulnerable; LRnt, lower risk, near threatened; DD, data deficient (NRE 2000).

Common name	Scientific name	Atlas records in or near Barmah Forest	Threatened status in Victoria
Common Long-necked Tortoise	*Chelodina longicollis*	11	
Murray River Tortoise	*Emydura macquarii*	2	
Wood Gecko	*Diplodactylus vittatus*	1	
Marbled Gecko	*Phyllodactylus marmoratus*	12	
Olive Legless Lizard	*Delma inornata*	1	
Eastern Bearded Dragon	*Pogona barbata*	7	
Tree Goanna	*Varanus varius*	16	DD
Carnaby's Wall Skink	*Cryptoblepharus carnabyi*	16	
Large Striped Skink	*Ctenotus robustus*	2	
Garden Skink	*Lampropholis guichenoti*	11	
Yellow-bellied Water Skink	*Eulamprus heatwolei*	13	
Grey's Skink	*Menetia greyii*	1	
Boulenger's Skink	*Morethia boulengeri*	54	
Peters's Blind Snake	*Ramphotyphlops bituberculatus*	1	
Woodland Blind Snake	*Ramphotyphlops proximus*	8	Vul
Tiger Snake	*Notechis scutatus*	2	
Red-bellied Black Snake	*Pseudechis porphyriacus*	17	
Eastern Brown Snake	*Pseudonaja textilis*	8	
Bandy Bandy	*Vermicella annulata*	1	LRnt
Carpet Python	*Morelia spilota metcalfei*	3	End

Appendix 4. Amphibians of Barmah Forest. Threatened species categories: CrEn, critically endangered; DD, data deficient (NRE 2000).

Common name	Scientific name	Atlas records in or near Barmah Forest	Threatened status in Victoria
Peron's Tree Frog	*Litoria peroni*	70	
Southern Bullfrog	*Limnodynastes dumerili*	59	
Barking Marsh Frog	*Limnodynastes fletcheri*	8	DD
Giant Bullfrog	*Limnodynastes interioris*	1	CrEn
Spotted Marsh Frog	*Limnodynastes tasmaniensis*	118	
Common Spadefoot Toad	*Neobatrachus sudelli*	8	
Bibron's Toadlet	*Pseudophryne bibroni*	1	
Plains Froglet	*Crinia parinsignifera*	62	
Common Froglet	*Crinia signifera*	54	
Sloane's Froglet	*Crinia sloanei*	3	

Appendix 5. Fish of Barmah Forest. Threatened species categories in Victoria: CrEn, critically endangered; End, endangered; Vul, vulnerable; DD, data deficient (NRE 2000). I, introduced to Australia.

Common name	Scientific name	Threatened status in Victoria
Silver Perch	*Bidyanus bidyanus*	CrEn
Goldfish	*Carassius auratus*	I
Common Carp	*Cyprinus carpio*	I
River Blackfish	*Gadopsis marmoratus*	
Broadfin Galaxias	*Galaxias brevipinnis*	
Flat-headed Galaxias	*Galaxias rostratus*	DD
Mosquitofish	*Gambusia holbrooki*	I
Western Carp Gudgeon	*Hypseleotris klunzingeri*	
Carp Gudgeon (×2 spp.)	*Hypseleotris* spp.	
Trout Cod	*Maccullochella macquariensis*	CrEn
Murray Cod	*Maccullochella peelii peelii*	Vul
Golden Perch	*Macquaria ambigua*	Vul
Macquarie Perch	*Macquaria australasica*	End
Crimson-spotted Rainbowfish	*Melanotaenia fluviatilis*	DD
Oriental Weatherloach	*Misgurnus anguillicaudatus*	I
Short-headed Lamprey	*Mordacia mordax*	
Southern Pigmy Perch	*Nannoperca australis*	
Bony Bream	*Nematalosa erebi*	
Rainbow Trout	*Oncorhynchus mykiss*	I
English Perch	*Perca fluviatilis*	I
Flat-headed Gudgeon	*Philypnodon grandiceps*	
Australian Smelt	*Retropinna semoni*	
Atlantic Salmon	*Salmo salar*	I
Brown Trout	*Salmo trutta*	I
Freshwater Catfish	*Tandanus tandanus*	Vul
Tench	*Tinca tinca*	I
Carp × Goldfish hybrid		I

The Murray River in *The Victorian Naturalist*

Natural History Notes

Mr. JG O'Donohue said that the manager of the Kulkyne Station, in a recent letter to him, mentioned that thousands of cormorants of several species were nesting at the present time in the Mournpoul sanctuary. In these particular locality these birds were not hitherto known to breed so late in the season.

From *The Victorian Naturalist* **XXXIII** (2), 18 June 1916.

The Distribution and Conservation Status of the Reptile Fauna of the Murray River Region in Victoria

Geoff Brown[1]

Abstract

The lands surrounding the Murray River, from source to South Australia, support a remarkable diversity of terrestrial reptiles. At least ninety-four species, representing nine families, are known from the environs of the Murray River in Victoria, and this fauna consists of a blend of arid-adapted elements from the north-west with temperate elements from the east. Species richness and diversity of regional reptile assemblages tends to increase along the gradient from cool mesic (Eastern Highlands) to warm dry regions (Mallee). Skinks are the dominant component (44%) of the overall reptile fauna in terms of number of species. Skinks also exhibit a distinct decline in proportional species composition along the environmental gradient from the east to the north-west, in contrast with dragons, geckoes and legless lizards, reptile families that show a steady increase in their proportional representation. Twenty-four reptile species known from the Murray River area are considered threatened in a national or state (Victoria or New South Wales) context, and at least another 18 species are considered locally threatened. The majority of these threatened species are found in the north-west of the state, and most are classified as such because they are either at the limit of their distributional range in northern Victoria, and consequently occur only rarely, or because they are habitat specialists and considered to be disadvantaged by habitat change or loss. The major determinants of reptile occurrence (and decline) are briefly discussed. (*The Victorian Naturalist* **119** (3), 2002, 133-143)

The Murray River

The Murray River is one of Australia's great rivers and, together with the Darling River, forms the catchment for a vast portion of south-eastern continental Australia. The headwaters of the Murray River rise in the Great Dividing Range at about 1430 m on the New South Wales-Victoria border and then flow westwards for 2530 km to the Southern Ocean in South Australia (Young and Hillman 2001).

Within Victoria the Murray River traverses a range of climatic zones (or 'natural' regions, after Conn 1993) over approximately 1900 km, extending from the high-altitude Eastern Highlands at its source, through the flat riverine plains of the Riverina region of north-central Victoria, to the Murray Mallee in the semi-arid north-west of the state. This environmental gradient is reflected in the climate, in increasing temperature and decreasing rainfall along a southeast-northwest axis, as well as in vegetation patterns and fauna assemblages. The vegetation along the Murray River ranges from montane forests and alpine woodlands of the mesic highlands of the Great Dividing Range in the east, through dryland and riverine woodlands (typically dominated by Black Box *Eucalyptus largiflorens*, Grey Box *E. microcarpa* or River Red Gum *E. camaldulensis*) of the plains of the Riverina, to the semi-arid habitats on dune-fields in the Mallee.

The dominant land use along the Murray River flood-plain is agriculture. Over the last century widespread clearing has enabled intensive and extensive cropping and grazing across large areas, particularly in the Riverina. Timber harvesting on public land is carried out, mostly in the highlands and riverine forests of the Riverina, although the target species and the purposes for which they are harvested vary. Fuelwood (dead and down material) is also a relatively important industry, for both commercial operators and individual licensees.

While sections of the Murray River area, notably the mallee habitats in the north-west and the open forests of the Eastern Highlands, are relatively well vegetated, much of the remaining plains have suffered extensive clearing, such that only a small and highly fragmented vegetation mosaic now exists. This mosaic includes mallee or woodland associations and consists principally of linear remnants along streamsides and roadsides, a handful of relatively large blocks that are typically riverine State Forests or State Parks, and a myriad of small vegetation parcels, generally located on private land. The amount of suitable habitat within the Murray River catchment, and its current management,

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has undeniable implications for the effective conservation of reptiles.

Species composition and distribution of reptiles along the Murray River

Ninety-four species of reptile, representing nine families, are known from the environs of the Murray River in Victoria (Table 1). These families include tortoises (3 species), dragons (9), geckos (9), legless lizards (8), skinks (41), goannas (2), pythons (1), blind snakes (4) and elapid snakes (17) (Atlas of Victorian Wildlife, NRE). These species incorporate an extremely diverse array of sizes, life-forms, habitat requirements and distributions. Taxonomy for reptiles in this paper follows Cogger (2000), except for Hooded Scaly-foot *Pygopus schraderi*, which follows James *et al.* (2001) .

This reptile fauna consists of a blend of arid-adapted elements in the north and west with temperate elements from the south and east. There is a strong trend of increasing species richness and increased diversity of taxonomic composition of regional reptile assemblages along the gradient from cool mesic to warm dry regions. Skinks are the most conspicuous component of the overall fauna in terms of both numbers of species and life-forms. They comprise 44% of the reptile species known from the area, and exhibit a marked decline in proportional composition of the reptile assemblage along the environmental gradient from the Eastern Highlands in the east (68%), to the Mallee region in the north-west (44%) (Table 1). A contrasting trend is apparent for dragons, geckos and legless lizards, reptile families that show a steady increase in their proportional representation in the species assemblage along the same environmental gradient. The highlands in the east exhibit the lowest species richness (27%).

Reptiles of the Murray River can be categorised into several groups, each of which reflects a distinctive distribution. Two major groups represent species that are relatively widespread across the region. One group, including species such as Common Long-necked Tortoise *Chelodina longicollis*, Large Striped Skink *Ctenotus robustus*, Boulenger's Skink *Morethia boulengeri*, Stumpy-tailed Lizard *Trachydosaurus rugosus* and Common Scaly-foot *Pygopus lepidopodus*, occurs in the Mallee and plains, but with few representative species in the highlands. The second group, which embraces such species as Tree Dragon *Amphibolurus muricatus*, Blotched Blue-tongued Lizard *Tiliqua nigrolutea*, Garden Skink *Lampropholis guichenoti* and Red-bellied Black Snake *Pseudechis porphyriacus*, occurs widely in the highlands and plains, but not in the Mallee.

Fig. 1. The Regal Striped Skink *Ctenotus regius* is an agile terrestrial skink that, in Victoria, is found in semi-arid grasslands and woodlands of the north-west.

The other groups have a more limited distribution across the region. A group of species occur only in the Mallee (e.g. Mallee Dragon *Ctenophorus fordi*, Regal Striped Skink *Ctenotus regius* (Fig. 1), Coral Snake *Simoselaps australis*, Mueller's Skink *Lerista muelleri*) and at the other end of the environmental gradient are those species that occur primarily within the highlands (e.g. Mountain Dragon *Tympanocryptis diemensis*, White's Skink *Egernia whitii*, Delicate Skink *Lampropholis delicata*, Highland Copperhead *Austrelaps ramsayi*). The Tessellated Gecko *Diplodactylus tessellatus* is an example of a true arid-zone species (Rawlinson 1971) that is found only in the extreme north-west. Its distribution in Victoria is marginal to its main occurrence in the drier interiors of the eastern and central Australian states (Cogger 2000), and follows the Murray River corridor (Atlas of Victorian Wildlife). Conversely, the Garden Skink and the Eastern Water Skink *Eulamprus quoyii* are true mesic species which also appear to use the mesic environments of the Murray River and Darling River respectively, to extend their main distributions from eastern Australia. The

Eastern Water Skink is known in Victoria only from the Mallee around the confluence of the Darling and Murray Rivers.

Overall, the Murray River reptile fauna includes three aquatic species (3%), all tortoises, 65 species (69%) that are considered terrestrial, seven arboreal (7%) species, eight species (9%) that are semi-arboreal, and 11 species (12%) that are fossorial (Table 1). The proportion of species categorised as terrestrial (e.g. many skinks and elapid snakes) systematically decreases from east to west. Conversely, the proportion of fossorial species and, to a lesser extent, those categorised as arboreal, increases from east to west. Fossorial species in the Murray River area consist of several species of legless lizards, the skink genera *Hemiergis* and *Lerista*, blind snakes and two species of uncommon elapid snakes. Most of these species are restricted to the Mallee.

Conservation status of reptiles

The conservation status of many reptiles in rural environments of Victoria, outside of the highlands, is alarming - while a small number of species (e.g. Marbled Gecko *Christinus marmoratus*, Boulenger's Skink) are relatively widespread and common, most species are patchily distributed (restricted to isolated remnant vegetation) and occur in very low numbers (Brown and Bennett 1995). There has been a widespread decline and local extinction of reptiles in the rural environment.

Overall, at least 94 reptile species have been recorded from the Murray River area, about one-quarter of which (25 species) are considered officially threatened in a national or state (Victoria or New South Wales) context (Table 1). At least another 18 species are considered locally threatened, on the basis of limited distribution and relatively low numbers of records (see Table 1).

These threatened Victorian reptile species include a locally extinct species, the Small-scaled Snake *Oxyuranus microlepidota*, two species that are 'Critically Endangered', seven that are 'Endangered', five that are 'Vulnerable', eight that are 'Lower Risk — near threatened' and another that is 'Data Deficient' (Table 1). The Common Death Adder *Acanthophis antarcticus* was also considered extinct in Victoria until recently, when an individual was recorded in the north-west corner of the state (Atlas of Victorian Wildlife, NRE). The majority (18) of these threatened species are found in the north-west of the state, whilst three are known from the Eastern Highlands and twelve from the Riverina.

Many of these species are classified as threatened because they are at the limit of their range in northern Victoria, and consequently occur only rarely. For example, species such as Tessellated Gecko, Beaked Gecko *Rhynchoedura ornata*, Hooded Scaly-foot *Pygopus schraderi*, Desert Skink *Egernia inornata*, Yellow-faced Whip Snake *Demansia psammophis* and Western Brown Snake *Pseudonaja nuchalis* all have broad continental distributions, yet extend only marginally into Victoria. Conversely, the Striped Legless Lizard *Delma impar* and Alpine Water Skink *Eulamprus kosciuskoi* are examples of threatened species that are typically confined to more mesic environments of south-eastern Australia.

Some of these threatened species, including the Striped Legless Lizard, Hooded Scaly-foot, Murray Striped Skink *Ctenotus brachyonyx*, and Carpet Python *Morelia spilota metcalfei*, are classified because they are habitat specialists and considered to be detrimentally affected by habitat change or loss (Robertson *et al.* 1989; Cogger *et al.* 1993). The Striped Legless Lizard, for example, is in a demonstrable state of decline because it is restricted to a particular habitat, native grassland, which has become exceedingly limited in area and is fragmented and prone to further reduction (CNR 1992; Dorrough and Ash 1999).

Two species, the Hooded Scaly-foot and the Alpine Water Skink, are considered 'Critically Endangered' in Victoria. The occurrence in Victoria of the Hooded Scaly-foot is known from three historical (undated) museum records, two records from the Riverina in the 1990s (Atlas of Victorian Wildlife, NRE) and most recently from the vicinity of Terrick Terrick National Park (P Robertson pers. comm.). At the opposite end of the environmental gradient, the Alpine Water Skink is known from a few localities, generally in alpine bogs, in the Eastern Highlands (Atlas of Victorian Wildlife, NRE).

Several other species that occur in the Murray River area of Victoria have apparently declined over recent years or are perceived to be threatened, especially by habitat loss or modification. Although abundant where it occurs, the Mallee Dragon appears to be restricted in Victoria to mallee habitat containing *Triodia* (Sadlier and Pressey 1994). *Triodia* is an important habitat requirement for other species, notably Brooks's Striped Skink *Ctenotus brooksi*, Obscure Skink *Morethia obscura* and Western Blue-tongued Lizard *Tiliqua occipitalis*, which show only a limited or patchy distribution in the state.

In general, the greatest threats to reptiles (i.e. those affecting the largest number of reptile species nationally) are habitat clearance, habitat modification, overgrazing by stock, urban development, and predation by introduced predators (Cogger *et al.* 1993).

Brown and Bennett (1995) found that the majority of reptile species in the Victorian Riverina, the most alienated natural region through which the Murray River flows, occurred in very low numbers or showed a patchy distribution. Their data, when coupled with existing distribution records and available biological and ecological data, signal low survival status and hence serious concern for the long-term security of the reptile assemblage of this region.

Although some reptile species are naturally rare in the Riverina, some are also rare because they are likely to have suffered more than others from the effects of clearing or disturbance. Large species, such as Tree Goanna *Varanus varius* (Fig. 2) and some of the elapid snakes (e.g. Tiger Snake *Notechis scutatus*, Red-bellied Black Snake), which have relatively large home ranges (in the order of hectares) are likely to be excluded from patches that are small and isolated. These larger species have naturally low densities, and therefore are especially prone to reduction in suitable habitat. The Tree Goanna, a solitary species known to inhabit only forest and woodland communities, typically shows a strong affinity with specific trees within its home range, which provide hollows for shelter (Greer 1989) and basking sites. Hence, timber harvesting is also likely to disadvantage this species.

Some of the small reptile species, especially skinks and legless lizards, are adversely affected by the modification of the structure of the ground-level strata (Brown and Bennett 1995). Grazing, the commercial collection of firewood, and the removal of litter and timber debris by land-holders are all common practices along the Murray River, particularly in the Riverina, and all involve the removal or alteration of elements of the ground-layer that many reptile species require for shelter, foraging or reproduction sites.

Fig. 2. Juvenile Tree Goanna *Varanus varius*, a large semi-arboreal species that is found in forest or woodland environments across much of Victoria.

Processes influencing the distribution and conservation status of species

The major impact of land use along the Murray River within Victoria has undoubtedly been the dramatic reduction in forest cover. This has been particularly acute in the Riverina, where forest cover diminished by 84% in the period 1869-1987 (Woodgate and Black 1988). A major consequence of this extensive clearing across the Basin has been the fragmentation and isolation of remnant vegetation, such that an array of different-sized patches now pepper the landscape. Many of these patches are small, less than 10 ha, and isolated. For the reptiles (and indeed, all fauna), the

Table 1. Conservation status, broad habitat, life-form and distribution for reptiles known from the Murray River area in Victoria. Categories for national and state conservation status, which follow those of the World Conservation Union (IUCN 1994), are derived from Environment Australia (website, 2001), NSW NPWS (website, 2001) and NRE (2000). Species listed under the Victorian Flora and Fauna Guarantee Act 1988 (FFG) are also indicated. Regional status refers to the Murray-Darling Basin of Victoria and is based on distribution (number of 5' grids in which the species has been recorded; Atlas of Victorian Wildlife) as well as total number of records. Broad habitat derived from Brown and Bennett (1995), Sadlier and Pressey (1994), Robertson *et al.* (1989), Cogger *et al.* (1993), Hutchinson and Donellan (1988, 1992), and P Robertson (pers. comm.). Life-form for each species is given as: aquatic (AQ), terrestrial (T), arboreal (ARB), terrestrial/arboreal (TA), or fossorial (F). Distribution: Mallee (M), Riverina (R), Eastern Highlands (EH). Conservation status: extinct (X), critically endangered (C), endangered (E), vulnerable (V), rare (R), lower risk - near threatened (LR) and data deficient (DD). Regional conservation status: restricted (R; <100 records or <50 5' grids), moderately distributed (M; 100-200 records or 50-150 grids), widespread (W; >200 records or >150 grids).

Species	Common Name	Broad Habitat	Life-form	Distribution			Conservation Status				Listed
				M	R	EH	Nat	Vic	NSW	Reg	FFG
Tortoises											
Chelodina expansa	Broad-shelled Tortoise	Rivers, streams	AQ	✓	✓			V		R	
Chelodina longicollis	Common Long-necked Tortoise	Rivers, streams, swamps	AQ	✓	✓	✓				M	
Emydura macquarii	Murray River Tortoise	Rivers, streams, swamps	AQ	✓	✓		R			R	
Dragons											
Amphibolurus muricatus	Tree Dragon	Dry forest	TA	✓	✓	✓				M	
Amphibolurus nobbi coggeri	Nobbi Dragon	Mallee, woodland and heathland	TA	✓	✓					M	
Ctenophorus pictus	Painted Dragon (Fig. 3)	Mallee woodland and heathland, grassland, chenopod shrubland	T	✓	✓					M	
Ctenophorus fordi	Mallee Dragon	Mallee *Triodia* and heathland	T	✓						M	
Physignathus lesueurii howittii	Gippsland Water Dragon	Riparian forest, rainforest	ARB (AQ)			✓				R	
Pogona barbata	Eastern Bearded Dragon	Woodland, agricultural land	TA	✓	✓					M	
Pogona vitticeps	Central Bearded Dragon	Mallee woodland, grassland, agricultural land, chenopod shrubland	TA	✓						M	
Tympanocryptis diemensis	Mountain Dragon	Dry forest, montane woodland	TA			✓				R	
Tympanocryptis lineata lineata	Lined Earless Dragon	Mallee heath, grassland, samphire shrubland	T	✓				E		R	L
Geckoes											
Christinus marmoratus	Marbled Gecko	Riverine woodland, dry forest and mallee	ARB	✓	✓	✓				W	
Diplodactylus intermedius	Southern Spiny-tailed Gecko	Dunefields, heathland, woodlands	ARB	✓	✓					M	
Diplodactylus tessellatus	Tessellated Gecko	Riverine shrublands and woodlands	T	✓	✓			LR		R	
Diplodactylus vittatus	Wood Gecko	Dunefields, woodlands, dry forest	T	✓	✓	✓				M	
Gehyra variegata	Tree Dtella	Chenopod mallee, grasslands, woodlands	ARB	✓						R	
Heteronotia binoei	Bynoe's Gecko	Chenopod mallee, grasslands, riverine shrublands	T	✓						R	
Lucasium damaeum	Beaded Gecko	Mallee, heathlands, woodlands, shrublands	T	✓						M	
Rhynchoedura ornata	Beaked Gecko	Belah woodland, riverine woodland	T	✓				E		R	L
Underwoodisaurus milii	Thick-tailed Gecko	Dunefields, woodlands, grasslands, dry forest	T	✓	✓					M	
Legless Lizards											
Aprasia inaurita	Pink-nosed Worm-Lizard	Mallee, heathlands	F	✓					V	R	
Delma australis	Southern Legless Lizard	Mallee	T	✓	✓					R	

Table 1 cont.

Species	Common Name	Broad Habitat	Life-form	Distribution			Conservation Status				Listed
				M	R	EH	Nat	Vic	NSW	Reg	FFG
Delma butleri	Butler's Legless Lizard	*Triodia* mallee dunefields	T	✓						R	
Delma impar	Striped Legless Lizard	Grasslands, agricultural land	T		✓		V	E	V	R	L
Delma inornata	Olive Legless Lizard	Woodlands, agricultural land	T	✓	✓	✓				M	
Lialis burtonis	Burton's Snake-Lizard	Mallee, dry forest	T	✓	✓					R	
Pygopus lepidopodus	Common Scaly-foot	Mallee, dry forest	T	✓	✓					R	
Pygopus schraderi	Hooded Scaly-foot	Shrublands and woodlands	T		✓			C		R	L
Skinks											
Bassiana duperreyi	Eastern Three-lined Skink	Dry forests, woodlands, heathlands	T		✓	✓				R	
Bassiana platynota	Red-throated Skink	Dry, open forests	T		✓	✓				R	
Carlia tetradactyla	Southern Rainbow Skink	Dry, open forests, woodlands	T		✓	✓				R	
Cryptoblepharus carnabyi	Carnaby's Wall Skink	Riverine woodlands and dry forest	ARB	✓	✓					M	
Ctenotus brachyonyx	Murray Striped Skink	Mallee, *Triodia*	T	✓						R	
Ctenotus brooksi iridis	Brooks's Striped Skink	Mallee heathlands	T	✓						R	
Ctenotus regius	Regal Striped Skink	Mallee, woodlands, grasslands, chenopod shrublands	T	✓						R	
Ctenotus robustus	Large Striped Skink	Mallee, heathlands, woodlands	T	✓	✓	✓				M	
Ctenotus taeniolatus	Copper-tailed Skink	Woodlands, open forest	T		✓	✓				R	
Ctenotus orientalis	Eastern Spotted Ctenotus	Mallee, heathlands, woodlands, chenopod shrublands	T	✓	✓	✓				M	
Egernia cunninghami	Cunningham's Skink	Woodlands, dry forest	T		✓	✓				R	
Egernia inornata	Desert Skink	Mallee	T	✓				LR		R	
Egernia saxatilis intermedia	Black Rock Skink	Moist and dry forests	T		✓	✓				M	
Egernia striolata	Tree Skink	Riverine and dry forest	ARB	✓	✓	✓				R	
Egernia whitii	White's Skink	Sub-alpine, moist and dry forests, woodlands	T		✓	✓				M	
Eulamprus heatwolei	Yellow-bellied Water Skink	Riverine moist and dry forests	T		✓	✓				M	
Eulamprus kosciuskoi	Alpine Water Skink	Alpine bogs	T			✓	R	C		R	L
Eulamprus quoyii	Eastern Water Skink	Riverine woodland	T	✓				LR		R	
Eulamprus tympanum	Southern Water Skink	Montane, moist and dry forests, woodlands	T		✓	✓				M	
Hemiergis decresiensis	Three-toed Skink	Dry forests, woodlands	F		✓	✓				M	
Lampropholis delicata	Delicate Skink	Moist and dry forests, heathlands	T			✓				R	
Lampropholis guichenoti	Garden Skink	Moist and dry forests, riverine woodlands, heathlands	T		✓	✓				W	
Lerista bougainvillii	Bougainville's Skink	Mallee, woodlands, grasslands, dry forests	F	✓	✓	✓				W	
Lerista muelleri	Mueller's Skink	Shrublands	F	✓				E		R	
Lerista punctatovittata	Spotted Burrowing Skink	Mallee, woodlands, grasslands	F	✓						M	
Menetia greyi	Grey's Skink	Mallee, woodlands, chenopod shrublands, heathlands, dry forests	T	✓	✓					M	
Morethia adelaidensis	Samphire Skink	Saline shrublands	T	✓	✓			E		R	
Morethia boulengeri	Boulenger's Skink	Mallee, woodlands, grasslands, shrublands, agricultural land	T	✓	✓	✓				W	
Morethia obscura	Obscure Skink	Mallee, heathlands	T	✓	✓					M	

Table 1 cont.

Species	Common Name	Broad Habitat	Life-form	Distribution M	Distribution R	Distribution EH	Conservation Status Nat	Conservation Status Vic	Conservation Status NSW	Conservation Status Reg	Listed FFG
Nannoscincus maccoyi	McCoy's Skink	Montane, moist and dry forests, heathlands	T		✓	✓	R			M	
Niveoscincus coventryi	Coventry's Skink	Montane, moist and dry forests	T		✓	✓				M	
Pseudemoia cryodroma	Alpine Bog Skink	Alpine wet heathlands	T			✓		V		R	L
Pseudemoia entrecasteauxii	Southern Grass Skink	Montane and dry forests	T		✓	✓				M	
Pseudemoia pagenstecheri	Tussock Skink	Tussock grassland, woodland	T			✓				R	
Pseudemoia rawlinsoni	Glossy Grass Skink	Montane swamplands and wet heathlands	T		✓	✓	R	LR		R	
Pseudemoia spenceri	Spencer's Skink	Sub-alpine, moist and dry forests	ARB		✓	✓				M	
Saproscincus mustelina	Weasel Skink	Moist and dry forests	T		✓	✓				R	
Tiliqua nigrolutea	Blotched Blue-tongued Lizard	Moist and dry forests, woodlands, heathlands	T		✓	✓				M	
Tiliqua occipitalis	Western Blue-tongued Lizard	Mallee woodland, *Triodia*	T	✓	✓			LR	V	R	
Tiliqua scincoides	Common Blue-tongued Lizard	Woodlands, dry forest, agricultural land	T		✓	✓				R	
Trachydosaurus rugosus	Stumpy-tailed Lizard	Mallee, woodlands, grasslands, dry forest	T	✓	✓					W	
Goannas											
Varanus gouldii	Sand Goanna	Mallee, woodlands, shrublands, dry forest	TA	✓	✓					M	
Varanus varius	Tree Goanna	Woodlands, moist and dry forests	TA	✓	✓	✓		DD		M	
Pythons											
Morelia spilota metcalfei	Carpet Python	Riverine woodland, dry forest	TA	✓	✓			E		R	L
Blind Snakes											
Ramphotyphlops australis	West Australian Blind Snake	Mallee, woodland	F	✓						R	
Ramphotyphlops bituberculatus	Peters's Blind Snake	Mallee, woodlands, grasslands, dry forest	F	✓	✓					M	
Ramphotyphlops nigrescens	Gray's Blind Snake	Dry forest, woodlands	F		✓	✓				R	
Ramphotyphlops proximus	Woodland Blind Snake	Dry forest, mallee	F		✓			V		R	
Elapid Snakes											
Acanthophis antarcticus	Common Death Adder	Not known	T	✓	✓		R	E		R	L
Austrelaps ramsayi	Highland Copperhead	Montane, moist and dry forests	T			✓				M	
Austrelaps superbus	Lowland Copperhead	Dry forest, woodlands	T		✓	✓				R	
Demansia psammophis	Yellow-faced Whip Snake	Mallee dunefields, agricultural land	T	✓				LR		R	
Drysdalia coronoides	White-lipped Snake	Moist and dry forests, heathland	T		✓	✓				R	
Furina diadema	Red-naped Snake	Riverine woodlands and shrublands	T	✓				V		R	L
Notechis scutatus	Tiger Snake	Riverine woodlands, montane, moist and dry forests	T	✓	✓	✓				M	
Oxyuranus microlepidota	Small-scaled Snake	Not known	T	✓				X	X	R	
Pseudechis porphyriacus	Red-bellied Black Snake	Riverine woodland, grassland, dry forest, swamps	T		✓	✓				M	
Pseudonaja nuchalis	Western Brown Snake	Mallee, woodlands	T	✓				LR		R	
Pseudonaja textilis	Eastern Brown Snake	Mallee, woodlands, dry forest, agricultural land	T	✓	✓	✓				W	
Rhinoplocephalus nigrescens	Eastern Small-eyed Snake	Dry forests, montane heathlands	T		✓	✓				R	
Simoselaps australis	Coral Snake	Mallee, woodlands	F	✓	✓					R	
Suta nigriceps	Mitchell's Short-tailed Snake	Mallee, woodlands	T	✓	✓					M	
Suta dwyeri	Dwyer's Snake	Woodlands, dry forest	T		✓	✓				R	
Suta suta	Curl Snake	Riverine woodland and shrubland	T	✓	✓			V		R	
Vermicella annulata	Bandy Bandy	Mallee, dry forest	F	✓	✓		R	LR		R	

immediate consequences are twofold: there is an overall reduction in the total amount of habitat that is available, and hence the overall size of regional populations; and secondly, the ability of species to persist in the developed landscape largely depends on their capacity to use small and isolated remnant habitats.

Brown and Bennett (1995), using reptiles of the Victorian Riverina as their focus, found that the distribution and abundance of reptiles in the rural environment is influenced by a number of factors, operating at different levels, including climate, landscape factors, major habitat types, microhabitat, grazing and timber removal. These are explored briefly below.

Climatic gradient

The environmental gradient (reflected in climate and vegetation) provides the overriding natural factor affecting reptile distribution. This is most conspicuously manifested in the biogeographical trend of increasing species diversity and abundance from the mesic east to drier, warmer habitats in the west. Reptiles are ectothermic, relying on external heat sources to determine body temperature, and using behavioural and physiological mechanisms to regulate it. As a consequence, more reptile species are found in arid and semi-arid habitats than temperate ones; arid zones in Australia support an extraordinary diversity of reptiles, in part because of their physiological and ecological adaptations to a dry, warm environment (Pianka 1986; Bradshaw 1986; James and Shine 2000).

Landscape factors

The pattern of remnant vegetation in the rural landscape influences the distribution of reptiles in several ways. Most species of reptiles depend on remnant areas of habitat and rarely occur in cleared farmland. Remnant vegetation displays great variation in its reptile fauna, and linear remnants, particularly roadside vegetation, typically yield the highest reptile densities and richness. This is partly attributable to the typically greater degree of substrate complexity on roadsides (compared with other remnant types), a result of the low levels or absence of grazing and the clearing of vegetation and coarse woody debris. Roadsides are usually managed by government agencies (Brown and Bennett 1995).

Fig. 3. The Painted Dragon *Ctenophorus pictus* is a terrestrial lizard that is generally restricted in Victoria to woodlands and shrublands in the north-east.

The Murray-Darling Basin overall, and in Victoria particularly, has suffered an extraordinary degree of habitat loss (Woodgate and Black 1988; MDBMC 1987; Goldney and Bowie 1990), an unfortunate consequence of which, at least for wildlife, is the creation of a more homogeneous landscape. Importantly, most of this clearing was undertaken on freehold land, and freehold land in this area now has less than 2% tree cover (Land Information Group, NRE). The effects on reptiles of clearing some vegetation communities are indisputable. In mallee vegetation, for instance, 70-95% of the original herpetofauna has been permanently lost from areas that have been cleared (Rawlinson 1981; Cogger 1989).

Another landscape factor which has a considerable impact on many species, particularly those that have small home ranges or are relatively immobile, is isolation (or degree of connectedness) of suitable habitat. The major impacts for reptiles arising from isolation appear to be a reduction in species numbers, a greater incidence and persistence of generalist species and an increased vulnerability to habitat disturbance or degradation. Recent studies have shown that even common species that are considered habitat generalists are affected by habitat clearance and the subsequent isolation of populations (Sarre 1995).

The fragmentation process affects reptiles primarily by progressive reduction in the amount of suitable habitat and the associated increase in the degree of isolation shown by many of these fragments. Also, fragmented remnants in farmland are more vulnerable to disturbance and degradation across edges.

Major habitat type

Major habitat types provide another factor affecting reptile occurrence. In the Victorian Riverina for instance, Black Box woodlands support more reptile species and families and reveal greater reptile densities, than River Red Gum forests (Brown and Bennett 1995). Although the major habitat types are correlated, in part, with the environmental gradient, some importance can be attributed to their influence as determinants of reptile distribution and abundance.

River Red Gum forests are noticeably depauperate in terrestrial reptile species; those species typically resident are relatively large, generalist species (Yellow-bellied Water Skink *Eulamprus heatwolei*, Tree Goanna, Tiger Snake, Red-bellied Black Snake) or arboreal species (Marbled Gecko, Carnaby's Wall Skink *Cryptoblepharus carnabyi*, Tree Skink *Egernia striolata*, Carpet Python) regularly recorded in semi-aquatic and flood-prone environments, usually in low numbers (LCC 1983; Brown and Bennett 1995). River Red Gum forest dominates watercourses and low-lying areas vulnerable to periodic flooding across the riverine plains. It is probably because this forest type experiences regular inundation that the proportion of terrestrial reptile species is relatively low, and that most fossorial species have rarely been recorded.

Microhabitats

Microhabitat characteristics are important determinants of reptile occurrence, after accounting for the environmental gradient. Generally, greater reptile numbers are correlated with increased structural heterogeneity, particularly in the ground-level and shrub strata. Open grazed grassland, or heavily-grazed woodland with bare ground are likely to support few, if any, reptiles.

Structural complexity near ground-level is clearly important to many reptile species, including a range of skinks (Downey and Dickman 1993; Hutchinson 1993), legless lizards (Rauhala 1993; Robertson and Edwards 1994) and elapid snakes (Shine 1987; Schwaner 1991). For example, the value of even modest vegetation cover for the habitat generalist Boulenger's Skink emerged during drought conditions in western New South Wales (Henle 1989).

Microhabitat is known to be an important element of niche partitioning in fossorial/terrestrial species, even more so than broad habitat type. To illustrate, the Spotted Burrowing Skink *Lerista punctatovittata* is an arid-zone resident and a habitat generalist for which abundance has been correlated with litter build-up and other ground-level substrates, such as timber and discarded corrugated iron, that afford shelter (Henle 1989). Other fossorial/terrestrial reptile species have also shown strong connections with various components of the terrestrial microhabitats, such as bark that has been shed naturally or piled following forestry activities (Bynoe's Gecko *Heteronotia binoei*; Bustard 1968a), well-developed litter (Three-toed Skink *Hemiergis decresiensis*; Robertson 1981), litter depth and proportions of bare ground and grass substrates (Coventry's Skink *Niveoscincus coventryi*; Brown and Nelson 1993).

A number of arboreal or semi-arboreal reptile species occur along the Murray River, and all require, to varying degrees, elevated microhabitats as foraging, basking or shelter sites. These species include geckos, dragons, skinks and goannas, and while some of them (e.g. some dragons, Sand Goanna *Varanus gouldii*) are flexibly arboreal, other species seem to be dependent on elevated microhabitats. For example, numbers of the strictly arboreal gecko Tree Dtella *Gehyra variegata* in western New South Wales are strongly correlated with the size, shape and density of Black Box (Henle 1990).

Modification of the microhabitat is clearly one of the most important processes governing reptile occurrence and abundance, and can arise in myriad different ways (e.g. fire, introduced animals, salinity changes, recreational impacts, altered water regimes, pollutants and biocides). However, the two activities that arguably have the most influence on habitat structure in rural environments along the Murray River are grazing and timber removal (both standing timber and coarse woody debris).

Grazing

Though few studies exist which examine the effects of different grazing regimes on reptile occurrence and density, the limited evidence suggests that excessive grazing has a significant impact on many terrestrial reptiles, both in Australia (where much of the evidence is inferential) (Recher and

Lim 1990; Cogger *et al.* 1993; Scougall *et al.* 1993; Smith *et al.* 1996; Brown 2001) and overseas (Busack and Bury 1974; Jones 1981; Brooks 1999). Grazing affects the microhabitat principally through the simplification of the understorey and ground-layer, seen in lowered structural and floristic diversity, altered floristic composition and soil disturbance. Species which live underground (e.g. *Aprasia* spp., *Ramphotyphlops* spp., Coral Snake, Bandy Bandy *Vermicella annulata*) or forage in the sub-soil and litter layers (e.g. *Hemiergis* spp., *Lerista* spp.) are likely to be most affected by impacts such as soil compaction and soil erosion.

Timber removal

Timber extraction clearly disadvantages those arboreal species that depend on elevated sheltering, basking and foraging sites (e.g. many geckos, Tree Skink, Tree Goanna) simply through the reduction of suitable habitat. The Tree Goanna, for example, uses tree hollows for shelter, exposed trunks and branches for basking, and includes eggs or nestlings of tree-nesting birds in its diet (Greer 1989; Green and King 1993). While timber extraction adversely affects a number of reptile species, this practice is known to benefit some species. For example, stumps resulting from the harvesting of *Callitris* eventually provide suitable microhabitats for Bynoe's Gecko and Tree Dtella, relatively widespread gecko species that are able to exploit the apertures that form between the bark and the stump (Bustard 1968b).

Many terrestrial species which rely on fallen timber for cover, activity and breeding sites are also disadvantaged by firewood removal. Eleven species were found to exploit logs in the Riverina (Brown and Bennett 1995); many species closely associated with them either for shelter or activity sites (e.g. Carnaby's Wall Skink, Garden Skink). The value of logs for a number of terrestrial and/or arboreal reptile species is well known (Webb 1985; Greer 1989). The decline of the Carpet Python in the semi-arid region of Victoria and New South Wales has been attributed to a number of different processes, amongst them the loss of hollow-bearing trees due to timber extraction, and firewood collection (Sadlier 1994; Shine and Fitzgerald 1996).

Conclusions

In summary, habitats along the Murray River are diverse and this is reflected in the wonderful variety of reptiles that are known from the river's environs. Whilst the conservation status for many of these species is stable in Victoria, a substantial number of species are considered threatened. The threats to reptiles generally vary according to land management practices along the river's course. What remains constant, however, is that the responsibility for ensuring the survival of reptiles, indeed all native fauna, is ours.

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Tadpoles of South-eastern Australia: a Guide with Keys

by Marion Anstis

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In the context of the Murray River, or indeed of any and all aquatic habitats in south-eastern Australia, this is the book I wish I'd written! But I didn't; and even if I had I wouldn't have been able to do it half as well as Marion Anstis has. Australian herpetology has been extraordinarily enriched by contributions from people without primary training in the field: such shining examples as Mike Tyler, Eric Worrell, George and John Cann, John Coventry and Charles Tanner come readily to mind. And now Marion Anstis has joined that distinguished company, with a flourish! Studying frog life histories has been a spare-time occupation for Marion, a full-time music teacher, for the years of field and laboratory work, photography, drawing and writing that went into the book. What if she had been in a position to pursue her passion for tadpoles full-time? – I dare say we would now be in a position to savour her books on the tadpoles of Australia, the southern hemisphere or the world…

The subtitle of Marion's book – *A Guide with Keys* – sums up its outstanding strength: it responds comprehensively to the naturalist's need for assistance in *identifying* tadpoles. If you want to know more about how tadpoles work, their anatomy and physiology, their behaviour, ecology and evolution, then you can turn to Roy McDiarmid and Ron Altig's encyclopaedic *Tadpoles: The Biology of Anuran Larvae* (University of Chicago Press, 1999). But if your interest is in your local tadpoles, the sorts of places to find them in, how they develop, and most particularly the sorts of frogs they'll turn into, then Marion's book is the very one you've been waiting for.

Tadpoles, it must be acknowledged, are difficult to identify; undoubtedly that's why it's taken so long for us to come to terms with them. For the taxonomist the saving grace of tadpoles is the mouth structure, of which more in a moment. For the rest, they are seriously deficient in measurable or countable things such as appendages, scales, fin rays or body segments; you have to rely on much less quantifiable characters, including body shape and form, fin depth and eye position. Very occasionally a tadpole has a bizarre, the-only-one-of-its-kind characteristic: the Glandular Frog *Litoria subglandulosa* of northern New South Wales provides one such example. For the most part, however, tadpoles are tadpoles are tadpoles. But their mouths are truly a marvel, the more so because not a vestige of the larval mouth structure remains in the frog, which has pretty regular jaws and teeth much more resembling yours or mine. Most commonly in tadpoles the jaws have a beak-like configuration, rather like that of a squid or octopus; they're made of keratin (horn) and are jet-black, with serrated edges. Surrounding them, typically, is a fleshy, folded disc, roundish or oval in outline, fringed by a single row or multiple rows of short papillae. The area between the jaws and the papillary fringe bears a number of rows of tiny, keratinous teeth, giving the appearance of a series of miniature black combs. The size and shape of the jaws, the disposition of the papillae and, most particularly, the number of rows of teeth and their arrangement, show consistent variations among species, meaning that the details of mouth structure are usually the most useful attribute of tadpoles for the identifier to home in on. And I guarantee that your first glimpse of a tadpole's mouth structure will absolutely delight you with its neatness, its complexity, its symmetry. The downside? – it's too small to really appreciate without a hand-lens or – vastly better – a stereoscopic microscope. Even then you need to gently manipulate the mouthparts if you want to be sure of seeing the fine details properly. (The lower photograph on p 141 of the book gives you a good idea of how much – or how little! – of the mouth structure you can

discern just by inspection. And the drawing below reveals what it's *really* like.)

What all this means, in the end, is that mere descriptions of tadpoles, no matter how good they are, are not going to unravel the mysteries of their identity. You need a key, and you need copious, excellent illustrations. I don't think you could ask any tadpole book to fulfil those prescriptions with greater inclusiveness, elegance and accuracy than Marion's has achieved. More than that, she has squarely confronted the problem that tadpoles change so much throughout their development that what will suffice to identify them at one stage will be of no use whatever at another. The magical mouth morphology, for instance, is not fully expressed in early larvae, so it isn't of much help. But you may well be put on the right track by, say, the presence or absence of external gills in a very early stage, structures which vanish altogether as the tadpole grows.

So something over one-sixth of the book is devoted to two very substantial and detailed keys, one to tadpoles and the other to eggs and embryos. To prevent the tadpole key from becoming too unwieldy, tadpoles are first classified into 17 general body types and their mouths (or 'oral discs') into 15. These are individually illustrated with line drawings; so when you encounter in the key 'Body type 10, oral disc type 8' (for instance), you can find out at once what you should expect to see. But there are also plentiful illustrations of other features of tadpoles: the position of the eyes, the shape of the body and tail, the locations of the spiracle (opening of the gill chamber) and the anus, the various pigmentation patterns, and so on. Similarly, for the egg and embryo key, there are colour photographs of egg-masses and drawings of egg and embryonic features.

Preceding the keys there is a general introductory section covering the classification of frogs, methods of collecting and caring for tadpoles (with reminders about legal and ethical constraints), issues relating to the conservation of frogs and tadpoles, and – perhaps most useful of all – an illustrated account of the stages of tadpole development, from Stage 1 (newly fertilized egg) to Stage 46 (newly metamorphosed froglet). The staging system is a standard one developed by American authors, but Marion has adapted it to better fit the local scene, and included extra drawings which illustrate some of the variation among Australian species. If you're describing tadpoles or taking measurements of their dimensions, it's crucial to note what stage they're at, and on pages 13-19 you'll find the means to do so.

The bulk of the book (190 pages) consists of species accounts; no less than 84 of the 89 species and subspecies of frog known to occur in New South Wales, Victoria and Tasmania are included. Since more than half of them were barely known or completely unknown before Marion's work, this is indeed a remarkable accomplishment. What is just as meritorious is that there are colour photographs of living tadpoles of all but three forms. Each account is headed with a colour photograph of an adult frog and a distribution map of the species; then follow descriptions of breeding sites, eggs, embryonic and larval development, tadpole behaviour, metamorphosis and similar species. The tadpole photographs usually include several views and sometimes several stages (the Holy Cross Toad *Notaden bennetti* and the Red-crowned Toadlet *Pseudophryne australis* are good examples; even though the caption of the *P. australis* photo is awry!). And even if you don't like tadpoles much you'll have to admit that some of them are simply gorgeous to look at: the Dwarf Tree Frog *Litoria fallax* on p 117, for example, or Haswell's Froglet *Paracrinia haswelli* on p 234. As well as the photos there are excellent drawings, first of a tadpole in left lateral view (to show the position of the spiracle, which is an important aid to identification, but rarely shows up in photos) and, second, of the oral disc. Although I don't believe tadpoles will ever be *easy* to identify, I do think that if you take full advantage of all the explanatory and illustrative material that accompanies Marion's keys, and if you make yourself generally familiar with the species accounts, you'll have a better chance than people anywhere else in the world of establishing what sort of frog the particular tadpole in your sights is going to turn into.

Errors and inconsistencies are few and minor as far as I can see. Tasmania's Moss Froglet is listed as *Bryobatrachus nimbus;*

it should (according to the latest opinion) be included in *Crinia*. Here and there a spot on a distribution map has gone astray: for instance the Victorian Smooth Froglet *Geocrinia victoriana* has acquired an outlier population near Jerilderie, NSW, and an even more remote one somewhere in the vicinity of Sydney! On the other hand, Banjo Frogs *Limnodynastes dumerilii*, correctly said to occur on Flinders Island, Tasmania, don't feature there on the map, and their occurrence on King Island, Tasmania, is overlooked altogether. Although there is a Glossary on p 8, you'll search it in vain for such technical terms as adhesive organ, pronephric bulge, and stomodaeal pit. And finally – in the interests of user-friendliness – I would have liked the page-headings to be more informative. Quite frequently, in the species accounts, you'll find yourself looking at a page of text and illustrations with the species name inconspicuous or absent: pages 134, 136 and 138-139 are a few among many examples. It means that if you're flipping through the book and glimpse a tadpole or mouth like the one you're trying to identify, you then have to turn back a page to find the name. Use of species names as page-headings would have avoided this minor inconvenience.

In sum, then, if you want to take advantage of the fact that – at last! – being able to identify south-eastern Australian tadpoles is a realistic prospect, this is the book you simply must have. Even if you're not a tadpole enthusiast, you may buy the book (as one friend has done) not for its usefulness, but just because it's such an outstanding example of how attractive modern field guides can be. In either case, warmest congratulations to Marion Anstis on a truly invaluable piece of work. Additional commendations to the Australian Biological Resources Study, to Rio Tinto and to the World Wide Fund for Nature, all of whom supported Marion's research and the production of the book. Well done, Reed New Holland, too, for achieving a quality of production that matches the quality of the research, and for holding the price at a reasonable level.

And my favourite tadpole? – the one featured on pp 130-132, the Heath Frog *Litoria littlejohni*. Why? Well, for one thing my respected mentor and colleague Murray Littlejohn and I were the first to study the life history and describe the tadpole of this species. That it was named for Murray, the person who has done more than anyone else to enrich our knowledge of Victorian frogs, is particularly pleasing. If it's permissible to dedicate a book review then I dedicate this one to him, on the occasion of a milestone birthday that he achieves on the very day that I'm writing this. But finally, the Heath Frog tadpole is just a delightful animal – big, velvety-black, always active (Marion describes it as 'agile'), easy to feed and care for, and nearly always successfully reaching metamorphosis in suitable captive conditions. If only every home could have one!

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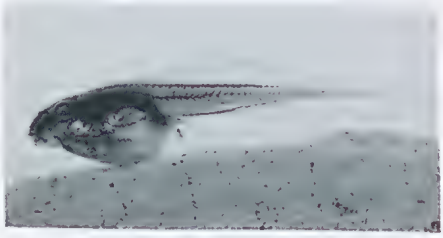

The tadpole of Peron's Tree Frog *Litoria peronii*, a common and abundant species in eastern and northern Victoria, including the Murray Valley. Photos by Marion Anstis.

Rivers as Ecological Systems: The Murray-Darling Basin

Edited by WJ Young

Publisher: *Murray-Darling Basin Commission, 2001. GPO Box 409, Canberra, ACT 2061*
Paperback, 336 pp, colour illustrations, $60. ISBN 1876830034

This ambitious book aims to summarise our knowledge of the ecology of the river systems of the Murray-Darling Basin, especially the effects of flow and flow change in these ecosystems. This is a laudable and timely objective as the availability and quality of water for irrigation, consumption and the environment is one of the major resource management issues currently facing Australia and the world. Overall, the book achieves this aim, providing a comprehensive summary of scientific and other literature related to the Murray-Darling Basin up to about 1999. I use the word summary rather than review deliberately here because review implies some critical evaluation and this book tends to report other people's results uncritically. The book seems to have been edited very consistently; the chapters are cross-referenced with no obvious changes in style between them, although the level of detail does vary between chapters. The contributing authors generally represent scientists with considerable expertise on their particular topic within the Basin. The book is also a remarkable collection of photographs of physical and biological characteristics of the Murray-Darling Basin. These photographs would make a very valuable resource for educators, both secondary and tertiary, if they were available in electronic form. I urge the Murray Darling Basin Commission to consider releasing a CD based on the book.

The range of topics covered is impressive and appropriate. The Introduction claims that 'It presents, for the first time, a comprehensive conceptual model for the major rivers of the basin ...' (page vii). This model is really the first part of the book (Understanding river systems) and while the material required for a conceptual understanding is included, there is not really any model, even informal, presented. The second part of the book deals with specifics of landscapes, flows and biota. Some of these chapters are the best summaries of relevant information for the Murray-Darling Basin available; in particular, I found the section on large plants very useful.

Like any book of this type, especially one with numerous authors across different chapters, there are some things that don't work so well. I have already mentioned the lack of critical evaluation of the literature. Similarly, there is usually no distinction made between information based on published data versus information based on observation versus information based on pure speculation. It is not that any of the information is obviously incorrect but that it is presented with no indication of the uncertainty associated with it. The chapters also vary quite a bit in the amount of detail and quantitative information provided. For example, chapter 4 (Landscapes, climates and flow regimes) is detailed with flow duration curves and hydrographs provided. In contrast, chapter 2 (River flow, processes, habitats and river life) is very descriptive, even though details such as cross-sections illustrating changes in river morphology would have been really helpful. There are also a few minor annoyances with the way the book is structured. There are no summaries of main points at the end of each chapter so main messages in each chapter tend to be lost. It is also an awkward book to cite because authors are associated with both chapters (e.g. Chapter 1) and sections within chapters (e.g. Chapters 5 and 6).

In the end, the main difficulty this book will face is finding its target audience. It is clearly not a 'coffee table' book designed for the general public, neither is it a textbook suited for a university course in river ecology, although I would imagine both these groups would find parts of the book very informative. It seems designed for professionals in a range of fields who are associated with the science or management of our river systems. Specialist ecologists or hydrologists will find useful information

throughout, and agricultural scientists, economists, engineers, etc. will find the book a valuable summary of the effects of flows on river ecology. My final comment, which is not meant to devalue the book in any way, is that I hope that parts of this book are quickly out of date. This will mean that research on the effects of flow on riverine ecosystems, and the Murray-Darling Basin in particular, is continuing and our knowledge base is improving. Despite the confident tone in some sections of this book, our limited understanding of the links between flow and river ecology is still a major constraint on successful management of one of Australia's most important resources, the rivers of the Murray Darling Basin.

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In which is incorporated the Microscopical Society of Victoria

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Murray River Special Issue Part Two

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The Murray River in *The Victorian Naturalist*

Notes of a Short Collecting Excursion to the Upper Murray

By Messrs C French and D Best
Read before the Field Naturalists' Club of Victoria, Nov 17 1884

In crossing a paddock, close to the railway line, we found quantities of a small but pretty composite, the name of which, with those of the other plants collected, have been identified and named by the kindness of Baron von Mueller. Some of the plants here collected, as also portion of those from Mulwala, he found to be of interest, and a complete list of all our specimens appears as an addendum to this paper. Turning over some logs, we were fortunate in finding a few specimens of a very handsome beetle, *Carenum* sp. which were the first of the kind taken by us.

We had not proceeded far before we came across a couple of the large Iguana (*Hydrosaurus varius*) common to the district, one being beautifully marked with yellow bands; but feeling sure of getting some on the day of our intended departure we did not attempt to capture it, which we now regret, as we did not again see a similar one, although we did many of the plain coloured, and of these we brought down two; the former although only a variety is much rarer than the latter.

We drove towards the Murray pine scrubs … a halt was here made, and a cockroach hunt suggested and improvised. This, we can assure our friends, was no ordinary cockroach hunt, for these bulky and somewhat repulsive looking fellows, burrow to a depth of nearly 2ft. into the sand, and forcibly reminded us of a wombat hunt on a small scale. We were fortunate enough, after digging for our bare lives, to find some of these Titanic cockroaches, which were speedily bottled up for our collections.

Proceeding along we came across our first Quandong tree, *Santalum acuminatum*, which to our great delight had a few ripe fruit on the top branches.

The Quandong here seems to be fast dying out, the cause being generally attributed to the clearing off for the improvement of the runs for sheep.

[We] afterwards did a little botanising in the surrounding pine scrubs, collecting a few orchids, amongst them being *Pterostylis rufa, var. Mitchelli*, this being considered somewhat of a rarity here.

From *The Victorian Naturalist* **1** (13), January 1885, pp 135-139.

The Murray River in *The Victorian Naturalist*

Wanderings on the Murray Flood-Plain

By JG O'Donohue
Read before the Field Naturalists' Club of Victoria, 8th February 1915

Whilst ranging through the Mallee we realized, at a very early stage in our peregrinations, that caution had to be exercised in the choice of a site whence to view a foraging bird. At every few yards the extensive and crater-like nests of the *Myrmecia nigricipes* were to be encountered. These ants appeared to be always spoiling for fight, and if one of us inadvertently approached within half a dozen yards of a citadel, or, for that matter, allowed his shadow to fall upon it, out they would pour in myriads, and, with gaping mandibles, skirmish over a large area in quest of the offender.

From *The Victorian Naturalist* **XXXII** (2), 10 June 1915, pp 25-35.

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Volume 119 (4) 2002
Murray River Special Issue
Part Two

August

Executive Editor: Merilyn Grey
Editors: Alistair Evans and Anne Morton

Fish of the Murray River, *by John Koehn* 152

Niche Segregation between Three Species of Freshwater Turtle in a Large Billabong During Flood, *by Catherine E Meathrel, Phillip J Suter and Nada M Radford* 160

Invertebrates of the River Red Gum Forests of the Murray River, *by Andrea Ballinger and Alan L Yen* 174

A Preliminary Survey of the Arboreal Invertebrate Fauna of Two River Red Gum Trees *Eucalyptus camaldulensis* near the Murray River, *by Alan L Yen, Simon Hinkley, Peter Lillywhite, John Wainer and Ken Walker* 180

Aquatic Macroinvertebrates of the Murray River, *by Phillip J Suter and John H Hawking* 186

The Swamp Yabby (*Cherax* sp.) of the Murray River Catchment, *by Geoffrey N Edney, Dale G McNeil and Susan H Lawler* 200

Murray River Microfauna, *by Russell J Shiel* 205

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Cover: Sweeping bend of the Murray River near Mildura. Photo by Anne Morton.

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Fish of the Murray River

John Koehn[1]

Abstract

Fish are an integral component of the Murray River, contributing to its biodiversity, ecology and cultural heritage, as well as providing commercial and recreational fishing opportunities. Fish are an important way of connecting the community to the river system. The number of species in the Murray River is low by world standards; species range from the large, well known Murray Cod to smaller, lesser known species, such as Australian Smelt. Seven fish species are considered to be nationally threatened, with several other species threatened on a regional basis. Many of the threats to the fish species relate to the use of water and its associated infrastructure. Changes to flows, barriers to fish passage, cold water pollution, snag removal and habitat alterations, commercial and recreational utilisation, and interactions with introduced fish species have all contributed to the decline in fish populations. Many of these threats are currently being addressed or under consideration for changed management regimes to reduce their impact. Issues such as the provision of more water for improved environmental flows will pose ongoing challenges. The restoration of riverine ecological processes is a key way by which fish populations may be restored, and this needs to be undertaken with the support of the community. (*The Victorian Naturalist* **119** (4), 2002, 152-159)

Introduction

Although they largely remain hidden under the water surface, fish are an integral part of the fauna of any river system. This is no more so than in the Murray River, where the legendary 'mystique' of large species such as Murray Cod *Maccullochella peelii peelii* transforms their importance from being merely fish species to becoming important components of our folk lore and cultural heritage. Fish provide a major way in which the community can be connected to the river and its fauna (Sinclair 2001). Whilst Murray Cod are well known because of their size and status as a species of commercial and recreational significance, there are many other species which are also important but lesser known. Fish are an important component of the biodiversity, ecology and culture of the Murray River.

The native fish and their status

The number of fish species in the Murray River is relatively low by world standards, totalling only about 30 native species (Table 1), several of which are restricted to the lower river zones and associated with marine or estuarine reaches. Whilst this number of species may be expected of a river with a relatively low overall discharge, it can be compared to the more than 1300 fish species described for the Amazon Basin (Cadwallader and Lawrence 1990) and highlights the importance of the need for conservation of individual species. The majority of the species is widespread along the river, although some have distributions more suited to either the upper or lower zones. For example, Two-spined Blackfish *Gadopsis bispinosus* occurs in the higher reaches, whilst species such as the Bony Herring *Nematolosa erebi* are only found in the mid and lower river zones. A further group of seven diadromous species, which require access to marine/estuarine waters to complete part of their life cycles, are found in the lower zones of the river. These species include the Pouched and Short-headed Lampreys; *Geotria australis* and *Mordacia mordax*, Short-finned Eel *Anguilla australis*, Common Galaxias *Galaxias maculatus*, Tupong *Pseudaphritis urvilii*, Estuary Perch *Macquaria colonorum* and Blue-spot Goby *Pseudogobius olorum*. Other essentially marine species such as Mulloway *Argyrosomus hololepidotus* would also have entered the lower, estuarine river reaches more frequently in the past.

The exact number of fish species present is not really known, with the taxonomy of several groups undergoing revisions, including the hardyheads (Atherinidae),

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Table 1. Species list (From Pierce 1988 and Cadwallader and Lawrence 1990) and conservation status for freshwater fish of the Murray River. EPBC, Environment Protection and Biodiversity Conservation Act 1999, Protection Act; ASFB, Australian Society for Fish Biology 2001 listing; CE, critically endangered; E, endangered; V, Vulnerable; Epop, endangered population in New South Wales; FFG, listed under the Flora and Fauna Guarantee Act, Victoria. P, New South Wales Protected species (i.e. no take); (P), Protected from commercial take; UC, under consideration.

		Listing			
		National		Vic	NSW
Common name	**Scientific name**	**EPBC**	**ASFB**		
Native freshwater species					
River Blackfish	*Gadopsis marmoratus*			DD	
Two-spined Blackfish	*Gadopsis bispinosus*				
Broad-finned Galaxias	*Galaxias brevipinnis*				
Flat-headed Galaxias	*Galaxias rostratus*		V	DD	
Mountain Galaxias	*Galaxias olidus*			DD	
Murray Cod	*Maccullochella peelii peelii*	UC		V, FFG	
Trout Cod	*Maccullochella macquariensis*	E	CE	CE, FFG	E,P
Golden Perch	*Macquaria ambigua*			V	
Macquarie Perch	*Macquaria australasica*	E	E	E, FFG	V,P
Silver Perch	*Bidyanus bidyanus*		V	CE, FFG	V,P
Southern Pygmy Perch	*Nannoperca australis*				V
Australian Smelt	*Retropinna semoni*				
Freshwater Catfish	*Tandanus tandanus*		V	V, FFG	(P)
Bony Herring	*Nematalosa erebi*				
Southern Purple Spotted Gudgeon	*Mogurnda adspersa*		E	CE, FFG	Epop
Western Carp Gudgeon	*Hypseleotris klunzingeri*				
Midgeley's Carp Gudgeon	*Hypseleotris* spp.				
Flat-head Gudgeon	*Philypnodon grandiceps*				
Dwarf Flat-head Gudgeon	*Philypnodon* sp.			FFG	
Crimson Spotted Rainbowfish	*Melanotaenia fluviatilis fluviatilis*			DD, FFG	
Murray Hardyhead	*Craterocephalus stercusmuscarum fluviatilis*	V		E, FFG	E
Agassiz's Chanda Perch	*Ambassis agassizi*			Ex, FFG	Epop
Native diadromous species					
Short-headed Lamprey	*Mordacia mordax*				
Pouched Lamprey	*Geotria australis*				
Short-finned Eel	*Anguilla australis*				
Common Galaxia	*Galaxias maculatus*				
Tupong	*Pseudaphritis urvillii*				
Estuary Perch	*Macquaria colonorum*				
Blue-spot Goby	*Pseudogobius olorum*				
Introduced species					
Brown Trout	*Salmo trutta*				
Rainbow Trout	*Oncorhynchus mykiss*				
Carp	*Cyprinus carpio*				
Tench	*Tinca tinca*				
Goldfish	*Carassius auratus*				
Redfin (English Perch)	*Perca fluviatilis*				
Gambusia	*Gambusia holbrooki*				
Weatherloach	*Misgurnus anguillicaudatus*				

galaxiids (Galaxiidae) (T Raadik pers. comm.) and gudgeons (Eleotridae), which include hybrid species (Bertozzi *et al.* 2000). New genetic techniques are also being used to investigate several other species and these taxonomic revisions could result in the description of new species. Eight introduced species are also present in the Murray River. One additional native species, the Broad-finned Galaxias *Galaxias brevipinnis*, is now present in the upper and mid reaches where it has been introduced from east coast rivers through flows from the Snowy Mountains Scheme (Waters *et al.* 2002). This normally diadromous coastal species appears to

be completing its life cycle landlocked in freshwater, as occurs in the highland lakes in Tasmania (Fulton 1990).

Fish species range in size from the Murray Cod, which is Australia's largest freshwater fish (recorded up to 113 kg), to smaller species such as the Australian Smelt *Retropinna semoni* which weighs only a few grams. Photographs, illustrations and detailed information on these fish species can be found in the following texts: Cadwallader and Backhouse (1983), Merrick and Schmida (1984), Koehn and O'Connor (1990a), McDowall (1996) and Allen *et al.* (2002).

It has been recognised that most native fish species in the Murray River have suffered major declines (e.g. Cadwallader 1981; Cadwallader and Gooley 1984). The causes of such declines have been discussed by many authors (e.g. Cadwallader 1978; Koehn and O'Connor 1990b; Kearney *et al.* 1999). There is concern about the long-term future of many species, with seven already being considered nationally threatened (Table 1), including the critically endangered Trout Cod *Maccullochella macquariensis* (Fig. 1) (Australian Society for Fish Biology 2001). The natural range of this species is now restricted to about 120 km of the Murray River, immediately downstream of Lake Mulwala. Whilst this species has been stocked from hatcheries into the upper Murray River and other sites, these fish have not yet formed self-sustaining populations. Many other species have reduced or fragmented ranges and are listed as threatened in either NSW or Victoria (Table 1). Concern has been expressed at the status of many of these species in South Australia (Pierce 1988).

The capture of Trout Cod and Silver Perch is now prohibited in both New South Wales and Victoria. Of particular community concern is the decline of many 'flagship' species such as Murray Cod, Trout Cod, Silver Perch *Bidyanus bidyanus* and Catfish *Tandanus tandanus*. These species are readily identified by the public, and their loss indicates that all is not well with the health of the river. The fish community in the lower Murray River has been listed as endangered in New South Wales (New South Wales Fisheries 2002) and under the Flora and Fauna Guarantee Act in Victoria (www.nre.vic.gov.au).

Fig. 1. Trout cod *Maccullochella macquariensis* is now critically endangered. The only remaining natural recruiting population occurs in the Murray River, downstream of Lake Mulwala.

Commercial fisheries for species such as Murray Cod, Golden Perch *Macquaria ambigua,* Silver Perch and Catfish have all been greatly reduced or ceased (Reid *et al.* 1997). Recreational angling remains popular and many native species such as Murray Cod and Golden Perch are keenly sought. Lake Mulwala provides one of Australia's premier Murray Cod fisheries but cod from it appear to use both the Murray and Ovens rivers upstream for spawning (Koehn 1996). This highlights the importance of tributary streams to the fish of the Murray River system.

Fish habitats, needs and threats

The state of fish habitats and threats to them vary along the river. Recent scientific assessments of flow and environmental impacts along the Murray River (Thoms *et al.* 2000; Jensen *et al.* 2000) highlight how threats change through the reaches (Table 2). For example, cold water pollution is an issue downstream of Lake Hume and Dartmouth Dam (on the Mitta Mitta River) and barriers to fish passage more an issue in the lower reaches. Many of the threats are related to the human use of water and associated infrastructure and the issue of environmental flows was a reoccurring one. In essence, fish need instream structural habitat and access to it, suitable water conditions in terms of quantity and quality and a functioning ecosystem to provide food resources.

The native fish present in the Murray River could be described generally as a 'warmwater' species assemblage. Water

Table 2. Major threatening processes for fish in the Murray River summarised from Thoms *et al.* (2000) and Jensen *et al.* (2000).

Reach	Major threatening processes relating to fish
Dartmouth Dam to Lake Hume	Constant flows, unseasonal high flows, reduced flooding, unseasonal water temperatures, reductions in snags
Lake Hume to Tocumwal	Constant flows, unseasonal high flows, reduced flooding, unseasonal water temperatures, reductions in snags
Tocumwal to Torrumbarry	Unseasonal high flows, reduced flooding, constant flows, reductions in snags
Torrumbarry to Wentworth	Reduced flows variation and flooding, reductions in snags, constant flows, barriers to fish passage, increased turbidity
Wentworth to Wellington	Reduced flooding, barriers to fish passage, reductions in snags, possible fish health impacts from Lake Victoria.
Lower lakes and Coorong	Reduced freshwater flows, barriers to fish passage

temperature is important for the functioning of fish populations, particularly for reproduction, larval survival and optimal growth. The release of cold water from low level outlets in impoundments poses a major problem to warmwater fish, restricting the success of spawning and may have detrimental effects on metabolic function and growth rates (Koehn 2001). This is highlighted in the upper zones of the Murray River where high volume, cold water irrigation releases occur from the low-level outlets of Dartmouth Dam and Hume Dam. Three species of warmwater native fish (Trout Cod, Macquarie Perch *Macquaria autralasica* and Murray Cod) have disappeared from the reaches of the Mitta Mitta River downstream of the Dartmouth Dam. It is likely that recruitment of these species has not been possible due to cold water releases during the spawning season of this species (Koehn *et al.* 1995). Low water temperatures from Lake Hume is likely to continue to restrict Murray Cod recruitment in the river downstream. The Murray River also receives water of unknown temperatures from the Snowy Mountains Scheme (Jacobs 1990). Cold water does however favour introduced species such as Brown and Rainbow Trout *Salmo trutta* and *Oncorhynchus mykiss* that can prey on smaller native species.

Reproductive strategies vary among species. Some species such as Golden Perch and Silver Perch produce up to 500,000 eggs which are laid in the water column and left without care by the parents. In contrast, species such as the River Blackfish *Gadopsis marmoratus* lay only a few hundred adhesive eggs on a wood substrate that are dependent on parental care. It has often been contended that many fish species have their recruitment aided by flooding, being able to exploit the high food availability on floodplains in times of floods. Whilst there is little evidence for use of the floodplain (Humphries *et al.* 1999), nutrients from the floodplain can be released during flooding and support an increase in production of algae, aquatic plants, zooplankton and other invertebrates that provide rich food sources for juvenile fish (Gehrke 1991). Reduced flooding, together with diminished flow levels could significantly decrease juvenile habitat availability and food production areas. A further complication is the clearance and replacement of native vegetation with flood intolerant exotic crops and pastures. Under such conditions, floodwaters rapidly become de-oxygenated as microbial communities decompose the flooded vegetation. This may adversely affect the survival of certain fish species, particularly when movement to other areas is restricted (Gehrke 1991; McKinnon and Shephead 1995).

Fish can be mobile, and many have a need to move widely throughout the river system. Species such as Golden Perch are mobile (Koehn and Nicol 1998), with some individuals migrating over 1000 km (Reynolds 1983). It has recently been discovered that high numbers of juvenile fish of species, such as Silver Perch, also move upstream (Mallen-Cooper *et al.* 1996), presumably to recolonise. Species, such as Murray Cod, which were previously thought to be sedentary have been shown to undertake pre-spawning migrations (Koehn 1997). Whilst these species may be

able to survive and reproduce even if such movements are not able to take place, their ability to recolonise and their ultimate survival and distribution over the longer term may be detrimentally affected. Lake Hume, Lake Mulwala and Torrumbarry Weir all pose barriers as do the many locks and weirs in the river downstream of Euston.

Many other species, especially those in the lower zones of the river, have parts of their life cycle that must be completed in saline water (normally the sea) and hence have to migrate to complete their life cycles. Barriers at the barrages (Murray mouth) prevent movements to and from the sea as well as preventing the occasional entry of many marine species. Some migrations are understood to occur in a particular season, for a particular reason, e.g. for spawning, and may often be affected by changes to flows. However, our understanding is not complete for all movements. Hence fish passage should be available to all species throughout the year. Aggregations of fish migrating upstream often occur immediately downstream of barriers (weirs and dams) making these fish very susceptible to capture by anglers.

Increases in water levels, both large and small, can stimulate the movement of fish (Mallen-Cooper *et al.* 1996). Reductions in flooding may restrict such movements, as might constant flow levels. The limiting of cues and the barriers to movement may affect spawning success and the distribution of species. Sudden reductions in flow levels can also lead to the stranding of fish.

Another form of fish movement is the drift of larvae (Koehn and Nicol 1998; Humphries and Lake 2000; Humphries *et al.* in press). This has the purpose of recolonisation and distribution of offspring, and can be affected by altered flow rates and impounded waters. High irrigation flows during early summer may mean that larvae are carried greater distances than would have occurred naturally. Impounded waters can trap larvae and prevent their distribution downstream. Such effects can alter the structure of fish populations. Larvae can also be transferred into irrigation channels where they are unlikely to survive (Koehn and Nicol 1998).

Fish numbers are often related to the amount of habitat available. Of course there must also be access to this habitat, which can be blocked by barriers. Snags or large woody debris are the major form of structural habitat in lowland rivers and are widely used by many species (Koehn 1993; Koehn and Nicol 1998). The use of this habitat by species such as Murray Cod has long been recognised (Koehn 1997). Snag removal has been widespread throughout the river, with snag numbers now considerably less than those that occurred naturally. Snags are used as home sites for territory formation, predator avoidance and prey detection. They offer protection from high water velocities, and are sources of food and spawning sites for many species. Snag removal has caused a major loss of fish habitat.

Many other floodplain habitats, such as billabongs and wetlands, have also been degraded, removed or made inaccessible. Habitats in the form of pools and scour holes can also be lost through infilling by sedimentation. Removal of snags and bank erosion can lead to a more uniform channel without a diversity of habitats. Variations in depth and velocities are also important to provide the suitable habitat for all species throughout their life cycle, and the presence of snags promotes such habitat diversity.

Eight introduced fish species are also present in the Murray River. Of these, Carp *Cyprinus carpio,* Redfin *Perca fluviatilis* and Gambusia *Gambusia holbrooki* are the most widespread. Carp receive the most public attention and are often blamed for many of the ills of the river. Recent reviews (e.g. Koehn *et al.* 2000) indicate that they are typical invasive species, which are tough and well adapted to making the most of already degraded riverine environments. With minimal predation pressure from reduced populations of native species such as Murray Cod and Golden Perch, Carp populations have expanded rapidly. Now in large numbers they contribute to water turbidity, uproot aquatic plants and utilise large amounts of habitat space. It is estimated they make up 90% of fish biomass in many reaches of the Murray River (Harris and Gehrke 1997).

The introduced salmonid species (mainly Brown and Rainbow Trout) are restricted mainly to the upper river zones (above

Lake Mulwala) and are keenly sought by some anglers. Together with Redfin, these species are formidable piscivores, which can impose predation pressure on smaller native fish species. Redfin populations appear to be reduced in many areas compared with the past (Cadwallader 1977), but this species persists throughout the river, particularly in still waters. Gambusia have been implicated in the harassment of fish through fin nipping and potential predation of eggs (Cadwallader and Backhouse 1983), but their impact on native species is not known.

Goldfish *Carassius auratus* are common, often in high numbers in the lower river reaches. Oriental Weatherloach *Misgurnus anguillicaudatus* are an aquarium species now present in the Murray River from Lake Mulwala to Barmah. Their distribution has increased downstream from the Ovens River. The impacts of this hardy species, which can survive in damp mud, is not known. Other introduced species such as Roach *Rutilus rutilus*, Atlantic Salmon *Salmo salar* and Brook Trout *Salvelinus fontinalis* have been recorded in the Murray-Darling Basin (Cadwallader and Lawrence 1990). Whilst not yet present in the Murray River, the coastal species Spotted Galaxias *Galaxias truttaceus* has also recently been recorded in the Campaspe River (P Humphries pers. comm.), presumably after a translocation.

Many of the fish species of the Murray River are or have been sought after for their commercial or recreational significance. Commercial fishing has undoubtedly taken a toll on numbers of some fish species in the past (Rowland 1989). Today however, most catch is from recreational take and this is not well quantified. Commercial native fin fishing now only continues in South Australia and this is likely to be reduced or phased out in the near future. The reduction of species other than those sought by fishers indicates that this was not the only cause for the decline of Murray River fish species.

Conservation efforts and the future

A Fish Management Plan for the Murray River was initiated in 1991 (Lawrence 1991) outlining management action to be taken to improve fish populations. This plan is to be superseded by a Native Fish Strategy (Murray Darling Basin Commission 2002) which will address key components for the restoration of native fishes across the Murray-Darling Basin, including the Murray River, over a 50 year time frame. Recently, the river has been assessed in relation to environmental flows and other threats, with many options for actions being canvassed (Thoms *et al.* 2000; Jensen *et al.* 2000). Several of the options discussed, together with other management actions, are already planned or under way. Some of these actions can be initiated readily whilst others must be structured over the longer term. The provision of better environmental flows was one recommendation which was seen to have the most benefit for the whole river (Roberts *et al.* 2001) and negotiations to improve environmental water allocation and its delivery are being undertaken through many different forums.

Options are now being considered for the remediation of cold water releases from Lake Hume. A fish lift has been installed at Lake Mulwala to assist with fish passage past that structure and a fully operational fishway has been installed at Torrumbarry weir (Mallen-Cooper *et al.* 1995). There is anecdotal evidence of increased numbers of Silver Perch upstream of Torrumbarry following the installation of that fishway. Modifications to existing, poorly functioning fishways and the construction of new fishways are intended for all structures downstream of Torrumbarry including the Barrages at the river mouth (J Barrett pers. comm.).

A considerable amount of research has been undertaken in the Murray River to improve our ecological knowledge of fish in this ecosystem. The general movements and habitat use of Murray Cod, Trout Cod and Golden Perch have been investigated (Koehn and Nicol 1998). Particular emphasis has been placed on investigating the downstream movements of fish, especially Golden Perch, with respect to interference to this type of movement caused by weirs (J O'Connor unpubl. data). Study of the downstream movement of fish larvae has also been undertaken. A resnagging project (adding large woody debris) has been undertaken downstream of Lake

Mulwala to provide additional habitat for Trout Cod and other species. This project has determined the structure and pattern of snags and is currently monitoring recolonisation by fish and macroinvertebrates. Study of movements and recruitment of carp around Barmah has highlighted this area as a likely key source of recruitment for the river (Stuart *et al.* 2001). This new information has been included in a new carp management plan for the area.

National recovery plans have been prepared for Trout Cod (Brown *et al.* 1998), Silver Perch (Clunie and Koehn 2000a) and Freshwater Catfish (Clunie and Koehn 2000b). Whilst the latter two plans are yet to be implemented, the ecology of Trout Cod has been investigated and monitoring of the Murray River population undertaken. Recent data indicate that this population is at least stable and may be expanding downstream. The provisions of fish passage at Lake Mulwala may allow this species to colonise the lake and expand its population upstream into the Ovens and Murray Rivers. Ideally, this would link the population to the fish currently being stocked in the Ovens River as part of the national recovery plan.

The restoration of ecological processes, such as migration, recruitment and organic production and cycling, must be recognised as key components for restoring the Murray River. With these processes in place, the fish populations then have a chance to re-establish and increase. This ecosystem approach to management must include the tributaries and catchments of the river. Ultimately, the management of the river must include and be supported by community ownership.

As a result of increased knowledge and recent and intended management actions, there are some positive signs for fish in the Murray River. The provision of fish passage throughout the river will allow the entry of some marine species, allow species with marine life stages to recolonise the river successfully and allow migratory fish within the river to move and recolonise freely. This should improve the distribution of species such as Tupong, and Silver Perch. More natural water temperatures downstream of Lake Hume can only be a positive for the recruitment of warm water species such as Murray Cod and Golden Perch. The provision of fish passage at Lake Mulwala may allow the Trout Cod and Silver Perch populations downstream to establish in the lake and rivers upstream. Additional water to meet environmental needs is still required to provide adequate environmental flow conditions to restore some of the key flow components, which maintain ecosystem processes. This will remain one of the biggest challenges for the restoration of fish populations in the Murray River.

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Niche Segregation between Three Species of Freshwater Turtle in a Large Billabong During Flood

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Abstract

During the summer of 1996/97 habitat and dietary overlap of three species of freshwater turtle, *Chelodina longicollis*, *C. expansa* and *Emydura macquarii* in Lake Moodemere, a large billabong in north-east Victoria, were studied to assess their level of niche segregation. Lake Moodemere was inundated by flood waters and was connected to the Murray River for the first four weeks of the study. Five separate habitat types of varying complexity were identified within the billabong, ranging from open water to dense reed beds. All three species of turtle preferred the more complex habitats in which to forage, but very few turtles contained food. During times of flood, all turtles appeared to become opportunistic and consumed any food items available. Prey refugia were unimportant during times of flood. (*The Victorian Naturalist* **119** (4), 2002, 160-173)

Introduction

The biodiversity of billabongs is greater than that of the parent river with which they are associated, and this is thought to be promoted by high productivity and environmental variability (Hillman 1986). The high levels of productivity of lower-order organisms in billabongs provide a plentiful food supply for higher-order consumers such as waterfowl, carnivorous fish and freshwater turtles (Carpenter *et al.* 1985). Turtles are an important element in the dynamics of Australian freshwaters. They occupy a complex trophic role, feeding on a large variety of plants, animals and microbes and via overland migrations can enter temporary water bodies that are inaccessible to other aquatic vertebrates (e.g. fish) (Chessman 1978).

Three species of turtle (family Chelidae) occur on the floodplain of the Murray River – the Eastern Snake-necked Turtle *Chelodina longicollis* (Shaw), the Broad-shelled River Turtle *Chelodina expansa* (Gray) and the Murray Turtle *Emydura macquarii* (Gray). Table 1 summarises the major differences between these three sympatric species (information taken from Goode 1967; Goode and Russell 1968; Legler 1978; Chessman 1983, 1984, 1988; Georges 1984; Georges *et al.* 1986; Kennett and Georges 1990; Legler and Georges 1993; Cogger 1996).

Most research into the ecology of *C. longicollis, C. expansa* and *E. macquarii* has been species-specific and comparative between rivers and billabongs (Chessman 1988; Kennett and Georges 1990). Limited previous research on sympatric chelids has suggested some degree of habitat and dietary overlap in the prey consumed, especially between the long-necked species (Chessman 1988; Legler and Georges 1993). There remains a paucity of quantitative research detailing the turtles' ecology.

Analyses of community dynamics depend on measurements of how organisms utilise their environment (Krebs 1989). The choice of niche by freshwater turtles is likely to be influenced by varying degrees of intra- and interspecific competition. The measurements of niche parameters of one species or population may be compared to that of another species or population. Food is one of the most important dimensions of the niche and the analysis of dietary preference of an organism is strongly related to the niche specifications of that organism (Krebs 1989). The three species of Murray River turtles all occurred in a large, permanent billabong on the Murray floodplain, Lake Moodemere, north-eastern Victoria. To assess competition between the three species of turtles two interactive niche dimensions were analysed (habitat and diet) over a four-month period from October 1996 to January 1997. Lake Moodemere was flooded at the start of the research. The billabong was connected to the Murray River (usually separated by

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Table 1. Comparison of the habits and size of the three turtle species found in the River Murray.

Species	*Chelodina expansa*	*Chelodina longicollis*	*Emydura macquarii*
Range	Murray-Darling system, central and coastal Queensland	Coastal and inland waterways from Queensland to South Australia	South Australia through Murray-Darling system to inland and northern NSW
Feeding strategy	obligate carnivore on motile prey, especially Hemiptera, fish and decapod crustaceans	opportunistic carnivore including carrion, decapod crustaceans and benthic invertebrates	omnivore, scavenger, especially on periphyton
Preferred aquatic habitat	permanent	shallow, ephemeral billabongs	large, permanent
Egg-laying season	late autumn	early summer	early summer
Nest substrate	heavy soils	heavy soils	light sands
Position within the water column	top	bottom	middle
Distance found from parent river	moderate	high	low
Average adult carapace length (cm)	43	25	31
Neck morphology	long	long	short

about 150 m) for the first month of the study and, as river levels subsided, the billabong became isolated. Turtles were captured in a number of different habitat types of varying complexity in order to test the null hypothesis that there would be no spatial overlap between the species. The null hypothesis that there would be no dietary overlap between species in any habitat type was tested by assessment of the type and abundance of prey available to each chelid species and this was compared with the prey actually consumed.

Methods

Study site

Lake Moodemere is a crescent shaped, ox-bow billabong situated 5 km west of Rutherglen in north-eastern Victoria (36° 03' S, 146° 23' E) that receives an annual rainfall of between 500-600 mm (Land Conservation Council 1983). Lake Moodemere was chosen for this study because large numbers of each species of turtle had been caught during the previous summer by researchers from La Trobe University.

On average, the billabong is 600 m wide and 2 km in length with a surface area of approximately 0.86 km^2. Because a 150 m channel to the Murray River was dug for water regulation, the billabong never dries out (Land Conservation Council 1983). Lake Moodemere is therefore classified as a perennial billabong (mean annual depth of 1.2 m) although surface area and depth vary seasonally and annually. At peak flooding in October 1996, the billabong measured 1.8 by 5.1 km, had reached 10 km^2 in area and was, on average, 3.8 m deep.

The billabong is surrounded by a community of closed grasslands and tall open forest dominated by River Red Gums *Eucalyptus camaldulensis*. Common species surrounding the billabong and its periphery are Giant Rush *Juncus ingens*, bulrush *Schoenoplectus* sp., Common Reed *Phragmites australis*, spike-rush *Eleocharis* sp., milfoils *Myriophyllum* spp., Floating Pond Weed *Potamogeton tricarinatus*, flat-sedge *Carex* sp. and Water Ribbons *Triglochin procerum* (Land Conservation Council 1983).

Classification of habitat types

In total, five distinct habitat types were determined for investigation (Table 2). These habitats were chosen on the basis of turtle prey refugia. For analysis, habitats were ranked by complexity. Habitat complexity was assessed on the basis of subjective estimations of the surface area available to turtle prey. It was assumed that the greater the surface area available,

Table 2. Classification of habitat complexity within Lake Moodemere, Victoria. * Reed beds contained areas of 1-5m² of open water within the reed bed. ** No areas of open water present.

Habitat	Habitat type	Relative width of stems or branches	Relative abundance of stems or branches	Reed bed width (m)	Complexity ranking
1	Open water	Nil	Nil	0	1
2	Woody debris	Broad	Low	0	2
3	Reed bed	Narrow	Low	2 – 3	3
4	Reed bed	Narrow	Medium	18 – 20*	4
5	Reed bed	Narrow	High	20 – 25**	5

the higher the complexity of the habitat, and the greater the number of prey items available to turtles. Estimations of surface area were calculated by the approximate width of reed stems or snags, multiplied by the relative abundance of the given refuge (reeds or snags). Water depth and temperature were measured in each habitat type during each sampling trip.

Assessment of prey in the habitat types

Samples of potential prey were collected from each habitat type during each trip. Invertebrates and small fish were collected from the water column, substrate and among refuge-type reed beds or snags to ensure a reasonable sample through the habitats. All reference samples were collected using a 200 µm mesh dip net with a mouth dimension of 0.29 × 0.25 m. All sweeps were for 20 seconds using a vigorous and continuous action. Invertebrates within the water column were collected by walking forward, so as not to collect organisms stirred up from the substrate, with the dip net circling up and down, back and forth. Invertebrates within the substrate were collected by walking backward and kicking up the substrate while circling the dip net 10 cm above the bottom. Reed beds were sampled for invertebrates and fish by vigorously thrusting the dip net amongst the reeds using an up, down and around motion. Invertebrates and fish associated with submerged branches were sampled by agitating the surface of the branches with the leading edge of the dip net. Specimens were preserved in 70% alcohol and later identified to order or family and counted. Only presence and absence of taxa were used for comparison with those found in the gut of turtles as the sweep net sampling method did not resemble turtles' hunting actions.

Collection and processing of turtles

Lake Moodemere was sampled continuously for turtles on two consecutive days each month from October to December and twice in January. Each field trip was conducted continuously between 10:00 hr and 13:15 hr the following day. This allowed each net in each habitat to be in the water for a total of 24 hours. All turtles were caught under the authority of the Victorian Department of Natural Resources and Environment (permit number RP-96-147) and the La Trobe University Animal Experimentation Ethics Committee (permit number LSC 9624).

Habitat preference for each species of turtle was measured by the abundance of each species captured in the five habitat types. Within each habitat in Lake Moodemere, two standard design fyke nets were placed randomly. Only areas that included the habitat type for at least 10 m either side of the net were sampled. Previous researchers have caught turtles using baited nets (Georges 1982; Georges *et al.* 1986; Bjorndal 1991). However, baited nets were not used in this study because it was thought that baits would attract turtles and cause an artificial habitat shift.

Nets in all five habitat types were checked and cleared every four hours. Once captured, turtles were returned to the shore in water-filled bins. There, all turtles were etched on the edge of a scute for recognition of having been captured. This ensured that no one turtle was sampled more than once for its gut contents. The first ten turtles above 15 cm carapace length for each species per trip were sampled for dietary analysis using stomach flushing (Legler 1977). This procedure took place as soon as possible, lasted approximately two minutes per turtle and always occurred within one hour of collec-

tion. Stomach contents were preserved in 70% alcohol. Once their stomach contents had been sampled, turtles were held until the next visit to their site of capture (i.e. maximum holding time of 4 hr). Turtles were not released immediately, as this would have required excessive disturbance in the vicinity of other nets.

In the laboratory, gut samples from turtles were examined under a stereo-microscope. Sand was assumed to have been accidentally ingested by turtles and was not included in the analysis of food items. Turtles that yielded no digesta were assumed to contain no material in the gut and were excluded from the analysis (following Georges 1982). Percentage composition by number, mass and frequency of occurrence were used to evaluate the relative importance of different foods eaten by turtles. The numerical method involved counting the number of items belonging to each taxonomic group. Aquatic insects and small crustaceans usually remained intact and were easy to count. Items that did not occur as discrete units (such as filamentous algae and carrion) could not be counted and were omitted from the numerical analysis. The diet of a turtle was assessed by combining the percent numeric, mass and frequency of food items in the stomach of a turtle and calculating an Index of Relative Importance (IRI) (Pinkas 1971) as follows:

Numerical percentage

$$= \frac{\text{occurrence of } FC_n \text{ in } I_n}{\text{total occurrence of all FC for all I}} \times 100$$

Mass percentage

$$= \frac{\text{mass of } FC_n \text{ in } I_n}{\text{total mass of all FC for all I}} \times 100$$

Frequency of occurrence percentage

$$= \frac{\text{total proportional occurrence of } FC_n}{\text{total proportional occurrence for all FC}} \times 100$$

where FC_n and I_n are food category and individual number 'n' respectively. The IRI gives the relative occurrence of the items in the diet for the numerical or mass value of a food type.

In total, 45 different categories were counted from stomach samples (Table 3). For analysis, these 45 categories were pooled into 12 (for turtles) and 11 (for reference collections) functional groups. These functional groups were based on general location and size of food items in relation to assumptions of how a turtle would distinguish them. Pooled groups only took into account organisms that were relatively similar in size and generally remained in the same area (as per Williams 1980 and Ingram *et al.* 1997).

Table 3. Stomach content items found in *Chelodina expansa*, *C. longicollis* and *E. macquarii* sampled in Lake Moodemere, Victoria. a, adult; l, larval stage.

Aquatic plants
Aquatic and terrestrial plant debris
Aquatic invertebrates
Aschelminthes: Nematoda
Annelida
Hirudinea
Oligochaeta
Arachnida
Arthropoda: Crustacea
Cladocera
Copepoda
Decapoda
Atyidae: *Paratya australiensis*
Palaemonidae
Parastacidae: *Cherax destructor*
Arthropoda: Insecta
Coleoptera (a)
Dytiscidae (a)
Hydrophilidae (a)
Coleoptera (l)
Diptera (a)
Diptera (l)
Ephemeroptera (l)
Hemiptera (a)
Corixidae
Notonectidae
Mesoveliidae: *Mesovelia* sp.
Odonata (l)
Plecoptera (l)
Trichoptera (l)
Mollusca
Bivalvia
Gastropoda
Terrestrial invertebrates
Arachnida
Insecta
Lepidoptera (l)
Vertebrates: Chordata
Teleostomi: Cyprinidae
Cyprinus carpio and *Carassius auratus*
Eleotridae sp.
Mucous and undetermined

Aquatic plants were separated from the rest of the plant debris found because these items were fleshy and of bite-sized pieces of stems and shoots. All other plant material, including terrestrial River Red Gum leaves,

Table 4. Functional grouping of organisms found in the stomachs of turtles and reference collections, Lake Moodemere, Victoria.

Functional group	Invertebrates	Justification
Benthic organisms	Hirudinae Trichoptera larvae Plecoptera nymphs Odonata nymphs Ephemeroptera nymphs Oligochaeta	All either crawl, sprawl or climb across (or just a centimetre above in the case of freshwater worms) the benthos
Surface film organisms	Terrestrial insects Diptera adults Mesoveliidae adults	All occur at or near the surface of the water
Littoral/pelagic/surface adult insects	Hemiptera	Adults move throughout the water column
Littoral/pelagic/surface larval insects	Coleoptera	Larvae move throughout the water column
Littoral/pelagic/surface and benthic adult insects	Coleoptera	Adults move throughout the water column and on the benthos
Pelagic zooplankton	Cladocera Copepoda	Zooplankton throughout the water column
Pelagic – active movement	Fish larvae and adults	Fish throughout the water column
Littoral and mobile	Decapod crustaceans	Occur on plants and substrate in the littoral zone
Littoral and sedentary	Mollusca	Occur on plants and substrate in the littoral zone

reed stems and small grass-like plant material, was termed plant debris.

Aquatic invertebrates were grouped into functional groups as described in Table 4. Benthic invertebrates included: Hirudinea, Oligochaeta, Ephemeroptera nymphs, Odonata nymphs, Plecoptera nymphs, Trichoptera larvae, because all either crawl, sprawl or climb across the benthos (Williams 1980; Ingram *et al.* 1997). Invertebrates associated with the surface included Diptera adults, adults of the family Mesoveliidae (Hemiptera) and all terrestrial invertebrates that had fallen onto the water. Except for Mesoveliidae, all other Hemiptera adults were swimmers and moved about the water column in the littoral, pelagic and surface zones. For this reason Hemiptera adults were kept as a separate functional group. Diptera larvae were kept separate as a group as not all occur near the surface; some can be found associated with the benthos. Coleoptera adults remained as a separate group because, although they were associated with the littoral and pelagic zones like Hemiptera, they were also associated with the benthos. Coleoptera larvae were retained as a separate group for this reason as well but they were not grouped with the adults as they occupy different niches. Cladocera and Copepoda were grouped as zooplankton. The decapod crustaceans, Atyidae, Palaemonidae (shrimps and prawns) and yabbies *Cherax destuctor* were all grouped together. The Mollusca (Bivalvia and Gastropoda) was classed as a distinct group. All fish adults and fish larvae were grouped because both were active within the water column.

Analyses of the dietary data were performed using hierarchical clustering and ordination programs in the numerical analysis package PATN (Belbin 1992). Similarity of diet was assessed using the Bray-Curtis dissimilarity measure clustered using Unweighted Pair Group ArithMetic Averaging (UPGMA). Hierarchical clustering was used because with a small to moderate data set (0 – 100), most relationships could be determined from a single dendogram (Belbin 1992). Resultant groups were confirmed by examining their positions in ordination space using Semi-Strong Hybrid multidimensional scaling (SSH). This grouped turtles or habitats into three dimensions.

The dietary indices of niche breadth and dietary overlap were calculated. Niche breadth was calculated using Levins' measure, $B = 1/\Sigma p^2_n$ where p = proportion of a food item 1 to n in a species (Levins 1968, cited in Krebs 1989), to assess the uniformity of distribution of dietary food items among the turtle species. Levins' measure was minimal when a turtle species contained only one food type (minimum niche breadth, maximum specialisation). The range of B was from 1 to n, where n was the total number of food types. To standardise niche breadth to generate B_A, B was expressed on a scale from 0 to 1.0, and was calculated by dividing B by the total number of food types (i.e. $B_A = (B - 1)/(n - 1)$).

Dietary overlap was calculated using Horn's index (R_o, Horn 1966) because it minimised biases associated with human observations of resource categories that animals may not distinguish (Krebs 1989) and was calculated as:

$$R_O = (\Sigma\, (p_{ij} + p_{ik}) \log_e(p_{ij} + p_{ik}) - \Sigma\, p_{ij} \log_e p_{ij} - \Sigma\, p_{ik} \log_e p_{ik}) / 2 \log_e 2$$

Data were analysed using either PATN or the SPSS statistical package (SPSS Inc. 1993) and all tests followed Sokal and Rohlf (1995). All means are presented ± 1 standard error unless otherwise stated.

Results

Lake Moodemere changed in depth significantly (one-way ANOVA, $F_{5,19}$ = 60.27, $p < 0.001$; Fig. 1) over the summer of 1996/97. The water level during October was at its highest when floods covered the region. An extra 2.8 m of water covered the billabong and joined it to the Murray River. In November the lake became isolated from the river and the water level was approximately 0.5 m above December and January levels. From December to late January the water levels decreased a further 0.2 m. Temperature increased gradually from October (17.2 ± 0.3°C) to late January (27.4 ± 0.5°C) ($F_{5,14}$ = 326.57, $p < 0.0001$).

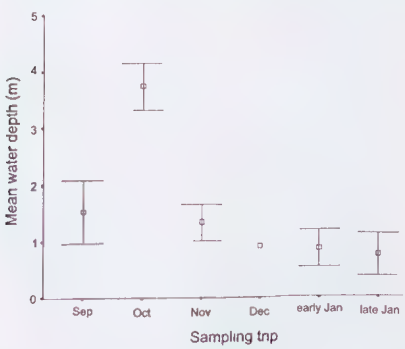

Fig. 1. Mean (± 1 SE) water depth at Lake Moodemere, Victoria during the 1996/97 turtle breeding season.

There was a significant difference in the number of freshwater turtles caught at intervals during the 1996/97 breeding season (χ^2 = 91.252, df = 3, $p < 0.001$). Only one *C. longicollis* was caught during October and three of this species in November. Most turtles were caught in early January (n = 46). During late January, turtle numbers decreased slightly (n = 31) but still exceeded the numbers caught in October and November.

The number of turtles caught in each habitat was dependent on habitat complexity (χ^2 = 42.021, df = 1, $p < 0.001$; Table 5). Turtles were caught most often in habitat five (highest complexity) and the least often in habitat one (lowest complexity). The total number of turtles caught per habitat was positively related to complexity (linear regression: $y = 0.675x + 0.275$; $p < 0.01$). The coefficient of determination, however, was low. Only 15% of the variation in turtle numbers caught could be explained by habitat complexity.

Prey availability and habitat complexity

The UPGMA classification enabled recognition of three habitat groups with a dissimilarity of 0.87 and showed a seasonal separation (Fig. 2). Group 1 consisted of all habitats during the flood and open water (lowest complexity) samples plus habitat five late in the season (highest complexity). Within the main cluster of this group was a tighter cluster of the open water habitats and habitat four and five of the November sampling. This indicated a strong similarity between the low complexity habitats and flooded habitats. This group was largely formed due to the greater amount of zooplankton present. Group two contained only habitat four, collected in December. This sample split was largely due to the high abundance of benthic invertebrates and the presence of aquatic Acarina and

Mollusca. Group three contained the late season samples from habitats of greater complexity. A greater amount of fish and Decapoda at this time of sampling were responsible for this grouping.

These groupings were confirmed by SSH ordination (Fig. 3). The stress for the three-dimensional plot was 0.067 and was accepted as a very good fit (Belbin 1992). For ease of presentation, the figure shows the three-dimensional configuration of reference samples as projected into the first two dimensions (first two axes). Group one clustered closely and indicated a strong association while group 3 was more broadly spaced.

Dietary preference of turtles

Stomach contents were flushed from a total of 15 *C. expansa*, 17 *C. longicollis* and 24 *E. macquarii* in Lake Moodemere between October 1996 and January 1997. The major component of food found in all species was plant debris representing >80% for all species (Fig. 4). The next most abundant food category in the diet of turtles was fish. Fish constituted approximately 20% of *C. expansa*'s diet and a minimal percentage in the other two species. *Emydura macquarii* was the only species to contain a minimal amount of aquatic plants. The remaining food categories were trivial to the overall proportion of dietary items consumed by each species of turtle.

All three groups contained the larger food categories such as Decapoda and fish.

Table 5. Frequencies of freshwater turtle species caught in Lake Moodemere, Victoria 1996/97 turtle breeding season. Habitat complexity is ranked from 1, lowest to 5, highest.

	Habitat					
Species	**1**	**2**	**3**	**4**	**5**	**Total**
Chelodina expansa	0	2	3	5	6	16
C. longicollis	0	5	1	10	12	28
Emydura macquarii	2	7	11	6	22	48
Total	**2**	**14**	**15**	**21**	**40**	**92**

There was a significant difference in the amount of fish, Hemiptera and Coleoptera larvae between species (one-way ANOVA, $F_{2,53} = 5.50$, $p < 0.01$, $F_{2,53} = 3.89$, $p < 0.05$, $F_{2,53} = 4.76$, $p = 0.05$). *Chelodina expansa* consumed more fish than both *C. longicollis* and *E. macquarii*; *C. longicollis* consumed more Hemiptera and Coleoptera than *E. macquarii* ($p < 0.05$, Scheffé's post-hoc tests).

The UPGMA analysis produced three groups at a level of 0.35 dissimilarity (Fig. 5). This low level of dissimilarity and each species occurring in each group indicated a high level of similarity of diet. The ordination plot for the analysis of turtles versus food categories eaten supported the groupings of the dendogram once food types responsible for the groupings were known (Fig. 6). The stress for the three-dimensional plot was 0.123 and accepted as a good fit (Belbin 1992).

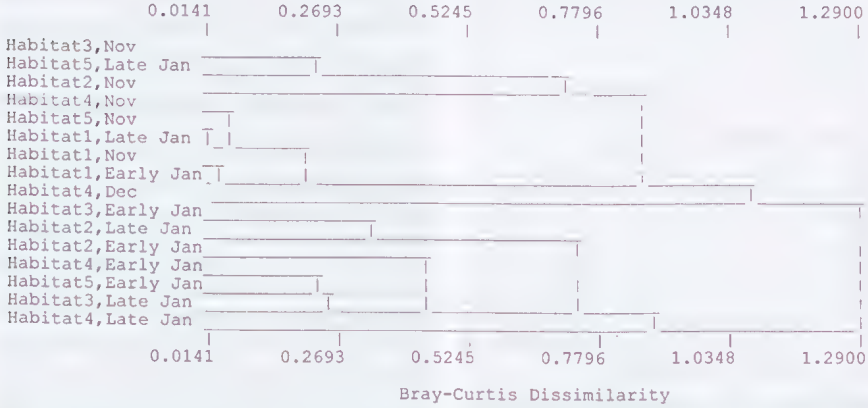

Fig. 2. Dendogram based on turtle food found within habitats over the 1996/97 season, from a Bray-Curtis association.

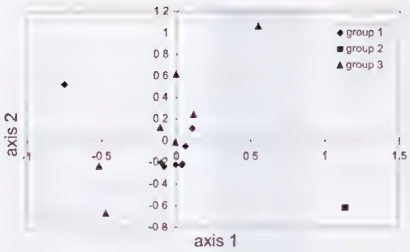

Fig. 3. SSH ordination plot in two-dimensions based on turtle food found within habitats from a Bray-Curtis association. Stress = 0.067.

Group one turtles clustered broadly, indicating a broad association between the turtles. The broad clustering on the ordination plot supported the high level of dissimilarity shown in the dendogram within this first group than the other two. This first group was responsible for a greater amount of food in the categories – plant debris, zooplankton and surface invertebrates. The turtles within this group had been eating more, and the variation of food eaten was reflected by the higher level of dissimilarity between turtles.

Groups two and three were tightly clustered on the ordination plot and indicated a close association between stomach contents of these turtles. Turtles within these two groups contained very little in their stomachs. They separated out on the dendogram because each contained slightly different food categories. Group two included aquatic plants and benthic invertebrates, and group three included very low amounts of fish, plants, aquatic plants, zooplankton and benthic invertebrates. The majority of turtles were in group three and indicated that most turtles did not contain very much, if any, food in their stomachs.

On a scale of 0 to 1, the Levins' value for niche breadth was low for all species. *Chelodina longicollis* had the most specialised diet with a niche breath of 0.0039. *Emydura macquarii* had a niche breadth of 0.0085, whereas *C. expansa* had the broadest (albeit still low) breadth of 0.0424.

The dietary overlap between *C. expansa* and *C. longicollis* (R_o = 0.9329) was high; so too, was the overlap between *C. expansa* and *E. macquarii* (R_o = 0.9244). This indicated that a number of similar food types were shared. *C. longicollis* and *E. macquarii* had the least overlap between their dietary niches (R_o = 0.1939).

Discussion

The number of turtles captured in this study was known to be lower than actual turtle numbers in the billabong, but were assumed to be a reflection of actual turtle abundance. The number of turtles caught could have been affected by a number of factors: being washed away by the flood, decreased net effectiveness with higher volumes of water, low temperatures and/or absence due to migration.

Turtles are ectotherms and consequently have a body temperature close to that of their environment (Begon *et al.* 1990). During lower temperatures in October, turtles may have been less active throughout the water column due to their reduced metabolism (Parmenter 1981, Zimmerman and Tracy 1989).

During the flood, the five habitats studied within Lake Moodemere were completely submerged. No reeds or snags were visible when the water depth reached 4.1 m and the submerged refugia no longer provided invertebrates with a substrate close to the water's surface. Williams (1980) has shown that many aquatic invertebrates move along or amongst the protective vegetation to the water's surface to breathe. Increased water levels and flow rates meant that these animals were probably swept away, or were more vulnerable to predation. However, given the large dilution effect of the flood, turtles were most likely unable to find prey in the deeper waters. Hence, turtles may have moved to the shallower habitats, leaving the main body of the billabong (the area of netting) in search of prey.

In November, the number of turtles caught remained low yet the water temperature within the billabong had increased and the water level had returned almost to normal, as indicated by water marks on the tree lines and reed beds. The bottom of the main body of the billabong was cooler and turtles may have sought warmer water in which to forage where the ectothermic invertebrates may have been more abundant (Chapman *et al.* 1996). When the water level receded, some turtles were

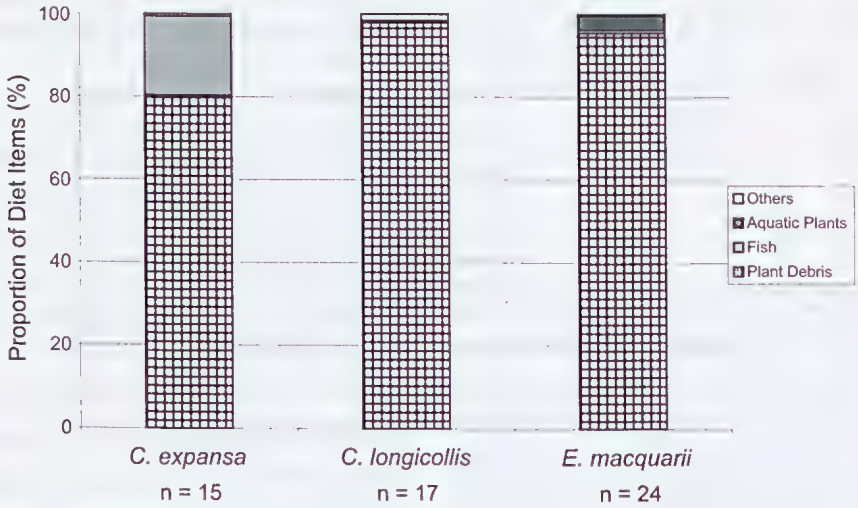

Fig. 4. Cumulative proportional IRI values of diet items in the three turtle species (*Chelodina expansa*, *Chelodina longicollis* and *Emydura macquarii*) from Lake Moodemere, Victoria during the 1996/97 breeding season.

stranded in smaller pools of water and were observed to cross land to return to the billabong. Crossing back to the permanent billabong was gradual as the smaller pools dried up and/or became devoid of food resources before larger pools.

The number of turtles caught in Lake Moodemere was maximal during January. This was probably the result of three factors: increased water temperature, increased immigration and decreased water level. The warm water in the main section of the billabong may have increased the activity levels of turtles, making them more apt to encounter a net during movement. Also, the immigration of turtles (Graham *et al.* 1996) from ephemeral billabongs (that were becoming too warm or too dry) into the main billabong would have increased turtle abundance within Lake Moodemere and hence, the probability of capture. Finally, an increase in the number of turtles moving around in the water column, coupled with the decreased water levels, would have increased the catchability of turtles.

Shallower areas in which turtles were thought to have occurred in the cooler October and November months were, in January, probably unfavourable habitats for turtles due to very warm and hypoxic water (Chapman *et al.* 1996). Turtles that had been using the shallower outer region of the billabong earlier in the season may have moved back into the main water body of the billabong in January. The turtles could now perhaps sustain a higher metabolic rate. Collections taken during this study indicated that invertebrates and fish were most abundant among the reeds and snags by this time. Consequently, the need for turtles to seek out other areas in which to forage may have become unnecessary.

No turtles were recaptured over the duration of this study, either from their original habitat of capture, or any other habitat. This suggested that turtles disperse widely throughout the billabong, and showed no habitat preference. Given the fluctuations in water level and temperature of Lake Moodemere during the 1996/97 turtle breeding season, it seems reasonable to suggest that preferences may not have been detected simply on the basis of the billabong being so dynamic. In years of greater billabong stability (i.e. non-flood years), habitat partitioning by turtles may be evident given enough netting over a variety of habitats.

After flooding, none of the turtle species appeared to have a preference for any particular habitat type. This suggested that all three species of turtle shared the same habitats within Lake Moodemere, and that the

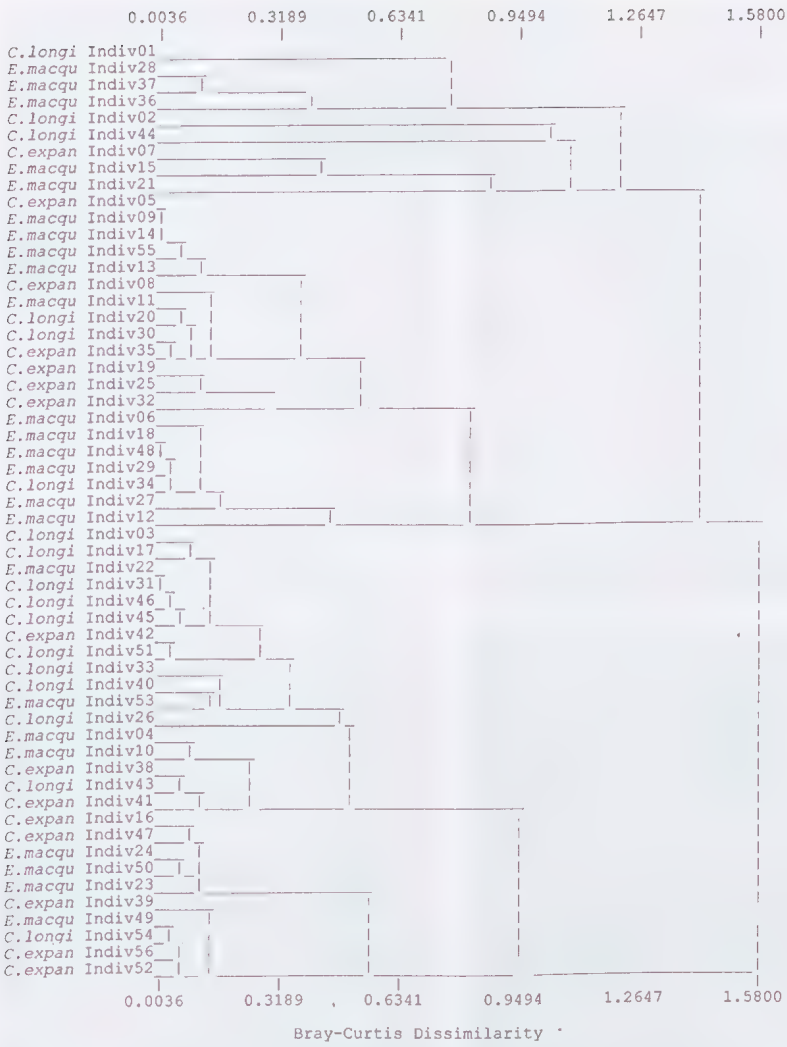

Fig. 5. Dendogram of turtles versus food eaten based on a Bray-Curtis association. *C. longi* = *Chelodina longicollis*, *C. expan* = *C. expansa* and *E. macqu* = *Emydura macquarii*.

niche requirements of each individual species were met within these shared habitats.

Turtles were caught more frequently within the medium to high reed bed areas with higher complexities, compared to open water areas of a billabong. This suggested that there were favourable conditions for turtles in areas associated with higher habitat complexities and a greater amount of prey. Unfortunately, the ordination of turtles by habitat type (Fig. 6) did not support this assumption, probably due to the limited number of dietary samples taken from each of the five habitats.

The reference collections of prey types were not distinguishable by habitat groups but rather by seasonal groups (Fig. 3), and suggested that although the same food categories were generally found within each habitat, their abundances varied temporally.

Plant debris was the dominant food item

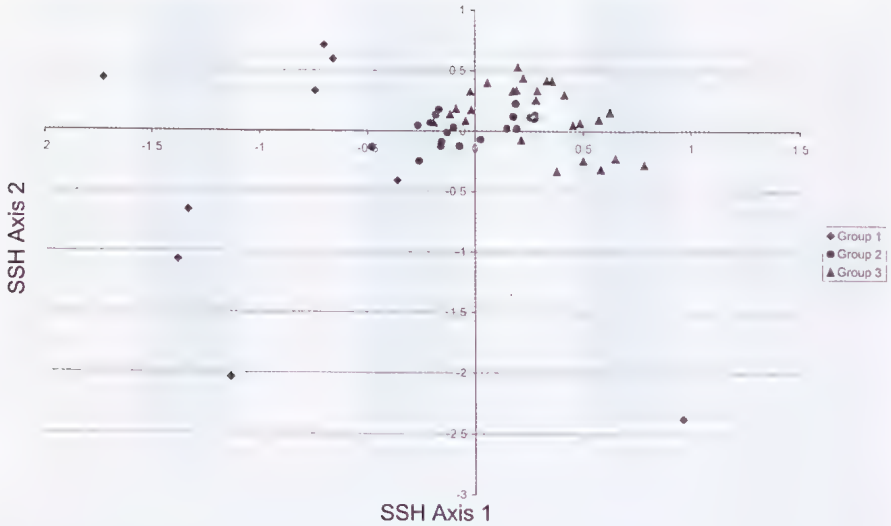

Fig. 6. SSH ordination plot in two-dimensions based on turtle diet from a Bray-Curtis association. Stress = 0.123.

in the stomachs of all species of turtle sampled from Lake Moodemere, even surprisingly, the obligate carnivore *Chelodina expansa*. Plant debris included reed stems and small particles such as seeds from terrestrial and aquatic plants. This material is primarily cellulose and, being difficult to digest, yields little nutritional value. Georges (1982) studied the diets of freshwater turtles in eastern Australia and considered this plant material to be unimportant and eliminated the food category from further analysis. Yet the ubiquitous presence of plant debris in the diet of turtles from Lake Moodemere suggested that some value must be gained (Bjorndal 1989). Vogt and Guzman Guzman (1988) studied the dietary preferences of freshwater turtles in Mexico. There, turtles retained a large proportion of plant debris in their diet (more than any other food type), especially when co-existing with other species of turtle. This same study also found that the absence of one species of turtle in a water body influenced the diet of the remaining species, with the dominant food source shifting from plant debris to insects. It seems sensible to suggest the presence of plant material in the diet of turtles may mirror a balance between quantity and quality. Turtles may sate themselves on plants when food of higher nutritional value (invertebrates) is less abundant. Conversely, plant debris may be passively ingested while turtles forage for benthic or littoral invertebrates (Legler 1978). The presence of plant debris in the obligate carnivore, *C. expansa*, may simply have resulted from passive ingestion.

Metabolic and digestive rates in reptiles vary in a mass-specific and thermal dependent manner such that gut passage time will affect the interpretation of stomach contents (Coulson and Coulson 1986). Smaller prey, such as zooplankton or insects, and softer bodied prey, such as shrimps *Paratya australiensis*, digest faster than larger or more indigestible prey. This implies that, if turtles are feeding on smaller, more easily digestible prey, they will be under-represented in the sample (Bjorndal and Bolten 1992). *Paratya australiensis* filter-feed on reeds and/or snags (Pringle *et al.* 1993) and the higher proportion of plant debris from reed remains may be linked to turtles passively ingesting reeds while feeding on shrimps.

Fish rated highly on the index of relative importance (IRI) scale, presumably because of their mass. Fish matter, though

highly digestible, was more abundant than smaller prey in the diet of the obligate carnivore, *C. expansa*. Research by Legler (1978) demonstrated that, when all species co-occur in highly-productive, ephemeral billabongs, resources are partitioned. Fish and shrimp are consumed primarily by the carnivorous species, with the omnivores concentrating on invertebrates and aquatic plants. When the turtles migrate back into more permanent billabongs, such as Lake Moodemere, resource levels are relatively lower and prey items are no longer partitioned (Chessman 1978).

After fish, the next most common dietary item sampled from Lake Moodemere turtles was aquatic plants. Interestingly, *E. macquarii* is the only omnivorous turtle in this billabong, and the only species observed directly to eat aquatic plants. This is consistent with the findings on the diet of this species by Chessman (1986).

After aquatic plants, the next most commonly occurring item in the diet of turtles from Lake Moodemere was aquatic insects. Adults of both Coleoptera and Hemiptera trap air beneath their hard, shell-like forewings (elytra) and in between microscopic, hydrofuge hairs on the body. The entrapped bubble of air may last several hours to days at low temperatures (Ingram *et al.* 1997). At the start of this study, the lower water temperatures would have meant that the activity of these diving beetles and bugs would have been less, owing to both their ectothermic existence and that a given amount of entrapped air would have lasted longer. As the water temperature increased towards summer, trips to the surface for oxygen replenishment by these insects would have increased in frequency, thereby increasing the time vulnerable to predation by turtles. Species of Coleoptera and Hemiptera known to stay under water permanently (Elmidae, Hydraenidae, Naucoridae) (Ingram *et al.* 1997) were not found in stomachs sampled during this study.

Corixidae, Notonectidae and Nepidae are totally aquatic families of Hemiptera, living within the water column (Williams 1980). These families come to the surface to renew air supplies, with the Corixidae and Notonectidae being very active. Mesoveliidae are associated with the surface film or on floating aquatic plants (Williams 1980). Of the Hemiptera found in stomach samples of turtles from Lake Moodemere, all were found in the water column or near the surface.

Overall, then, the diet samples taken from turtles in Lake Moodemere suggested that resources were shared over all habitats. The high proportion of plant debris in their diets indicated that most turtles were essentially omnivorous, eating softer-bodied animals and passively ingesting plants. However, caution must be exercised when suggesting the method of prey selection based on so few samples. Also, sampling was conducted over a 24 hour period on five occasions. There is no information in the literature regarding how frequently turtles feed in the wild. Clearly, samples from daily foragers would differ from those of weekly foragers. Hence, the samples obtained in this study may not truly indicate the degree of resource partitioning between these species.

All of the turtle species occupying Lake Moodemere showed an extremely narrow niche breadth and a high degree of dietary overlap, which suggested that turtles were competing for a limited resource, in this case food. The relationship between competition and niche overlap is complex (Krebs 1989). For instance, zero niche overlap does not mean that interspecific competition is absent. Conversely, niche overlap does not always imply competition. In many cases niche overlap is only used as a descriptive measure of community organisation (Krebs 1989). However, high overlap occurs in both diet and habitat during periods of resource scarcity if animals do not disperse widely.

On a niche breadth scale of 0 to 1, all turtle species in this study would be classified as dietary specialists. Recall, however, that *C. expansa* is an obligate carnivore, *C. longicollis* is an opportunistic carnivore and *E. macquarii* is an generalist omnivore in ephemeral billabongs or when all species do not co-occur within a given habitat (Chessman 1983, 1984, 1986). Assuming that sufficient samples were obtained during the study to show the degree of dietary specialisation of each turtle species, it would seem that there was a low diversity of prey species available to the turtles. This

may have resulted from the post-flooding dilution effects making only certain prey taxa vulnerable to predation.

Given the high degree of dietary overlap found between the turtles in Lake Moodemere, a particular type of food may have been a limiting resource. Dietary overlap was highest between the two carnivores (*Chelodina expansa* and *C. longicollis*), as expected. It was also high between the obligate carnivore (*C. expansa*) and the omnivore (*E. macquarii*). Interestingly, dietary overlap was lowest between the opportunistic carnivore (*C. longicollis*) and the omnivore. Relative to other billabongs, Lake Moodemere is lacking in macrophytes (pers. obs.). Therefore, it was possible that the omnivore shifted toward a more carnivorous diet, partitioning the animal prey between all three turtle species.

When food is both diverse and abundant within the billabong, in this case after the flood, interspecific competition for food resources may be lessened. Too few turtles were sampled during and immediately after the flooding event to discern if interspecific competition was reduced at that time. When water levels dropped and the temperature within the billabong increased, a substantial number of turtles were captured (n = 54). The high degree of dietary overlap, suggesting competition for food, may have been an artefact of competition with other predators at the billabong.

Other major consumers of zooplankton and macroinvertebrates in billabongs include several species of water birds and native and introduced fish (Hansson *et al.* 1978; Bunn and Boon 1993). Lake Moodemere is considered to have an over abundance of Red-fin *Perca fluviatus* (G Closs pers. comm.); many small members of this species were caught in this study. The perch population is considered density-dependent because there were many stunted individuals. As for many density-dependent fish, their large numbers and reduced size result from high levels of both inter- and intraspecific competition (Liebold 1996). Studies on the diets of fish in billabongs (Harris 1985; Barlow *et al.* 1986; Rowland 1992 in Ingram *et al.* 1997) have shown that fish commonly eat Coleoptera, Diptera, Hemiptera, Odonata and Trichoptera, all of which are eaten by turtles. Competition from Red-fin and occasional Golden Perch *Macquaria ambigua* may decrease the amount of food available to turtles, forcing the turtles to seek non-preferred foods. This may have been reflected in the amount of plant debris.

The majority of turtles caught in Lake Moodemere contained very little in their stomachs, reflecting the limit in food availability. Turtles that had empty stomachs clustered more tightly on the ordination plots and dendograms simply because they were empty. The turtles with more food items in their stomachs tended to eat a wider variety of food types, rather than specialise, although their niche breadths were still quite low. This explains why there was no separation of turtle species on the dendograms, because only nine individuals contained a substantial amount of food. Given the limited sample size, it was decided to include the rarer food types in the diet of turtles. Exclusion of rarer taxa may have reduced 'noise' around patterns seen in the dendogram and ordination plots (Faith and Norris 1989), but the end result would, most likely, not have changed.

The spread of all three species throughout the dendograms' groups indicated that all three species of turtle were eating essentially the same food, from the same habitats. Turtles did not appear to favour any one particular habitat type or prey item.

The habitat and prey selectivity displayed by turtles in this study may not reflect the present conditions, but those learned previously. For instance, the three species of turtles may have shared resources in this study, not as a reflection of the current post-flood conditions when resources were presumably abundant, but as a reflection of other seasons. In these perhaps more 'typical' years, water levels are lower, habitat diversity is lower and food resources may be limited. As such, the turtles may overlap in time, space and the utilisation of all resources in this closed system.

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Invertebrates of the River Red Gum Forests of the Murray River

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Abstract

The Murray River is surrounded by River Red Gum forests for much of its length. These forests are habitat to a rich and diverse invertebrate fauna, both in the dominant River Red Gum trees and in the surrounding ground layer. A brief introduction is provided to some of the important ecological roles played by invertebrates in these forests. The responses of some of these invertebrates to flooding is discussed. (*The Victorian Naturalist* **119** (4), 2002, 174-179)

Introduction

River Red Gum *Eucalyptus camaldulensis* forests are a dominant feature of the Murray River floodplains. Yen *et al.* (2002) recorded 6,666 invertebrates from over 450 species when the canopy of two individual trees was sprayed with insecticide. What do all these invertebrates do? While inventory of the invertebrate fauna is an essential first step in understanding what they do and how they interact with each other, there is still much to be done before we have a clear understanding of the structure and function of the invertebrate fauna. Yet, with the limited information available and with research currently in progress, we can still outline some of the important roles that invertebrates play in these forests.

In this paper we provide examples of invertebrate fauna typical of River Red Gum forest and present a guild approach as a means of coping with the sheer diversity of arthropods. We then use flooding as an example of how the guild approach can be used to understand the impact of ecological processes on invertebrate assemblages.

Invertebrates of the River Red Gum tree

The canopy invertebrate fauna of *E. camaldulensis* is dominated by herbivorous insects and their associated parasitoids and predators. There are, however, other types of invertebrates present, such as pollinators and scavengers. The invertebrates on River Red Gum can be grouped into three broad types: (1) species that feed on River Red Gums; (2) species that feed on other invertebrates; and (3) the remainder. The following information is based on Moore (1966), Morgan (1986), Stone and Bacon (1994), Collett (2001), Yen (unpubl. data), and Ballinger (unpubl. data).

Species that feed on River Red Gums

Foliage (leaf) chewers are insects that bite off whole chunks of leaf. There is a range of species, primarily amongst the beetles (such as the chrysomelid *Paropsis atomaria*, the scarab *Anoplognathus montanus*, the weevils *Gonipterus* spp.), as well as tree crickets. Black masses of the pergid sawfly *Perga dorsalis* are often seen moving on the trees in search of suitable foliage.

Other chewing-type insects feed differently on the leaves. Some insects, predominantly the caterpillars of several species of moth, only feed on one surface of the leaf; their feeding exposes the leaf veins to give the appearance of a skeleton. One of the most common caterpillars to feed in this way is the Gumleaf Skeletoniser, *Uraba lugens*. A variation of this feeding behaviour involves moth larvae that bind two leaves together with silk and skeletonise the leaves on the inner surfaces.

Leaf miners feed between the upper and lower epidermis of leaves. The adult female oviposits into the leaf, and the larvae feed as they move through the tissue. The feeding produces an often species-characteristic pattern on the leaf. Most leaf miners are flies or moths. Examples include the agromyzid fly *Japanagromyza eucalypti* and the incurvariid moth *Perthida* sp.

Gall-inducing insects also lay eggs into the plant tissue. However, unlike leaf miners, ovipositing gall-inducing insects release chemicals that induce the plant to produce extra tissue, which the developing larvae then feed on. The shape of the gall is usually characteristic of the species. Gall-inducing insects generally belong to

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the flies, wasps and true bugs. Examples are the fly *Fergusonina* sp. (Fergusoninidae) and the coccoid *Apiomorpha frenchi* (Eriococcidae).

The Hemiptera (or true bugs) use stylet-like mouthparts to feed. Some are sap-suckers on leaves, such as the white lace lerp, *Cardiaspina albitextura* while others, such as the scale insect, *Eriococcus coriaceus*, feed on twigs. Leafhoppers (Cicadellidae) are especially common on River Red Gums, and include the wafer-thin nymphs of *Stenocotis* spp.

High numbers of invertebrates are found when the River Red Gum flowers. Adults of many species depend upon nectar and pollen, although their immature stages have completely different feeding habits: buprestid beetle larvae are wood borers, ichneumonid wasp larvae are predators, and calliphorid fly larvae are carrion feeders. Other visitors include thrips (*Phlaeothrips* spp.), flower wasps, and ants. One of the visitors that arrived after European settlement is the Honey Bee *Apis mellifera*.

The bark of River Red Gums is shed, but not completely detached from the tree, providing ideal habitat for subcortical fauna (Baehr 1990). Bark probably functions primarily as a protective environment, rather than acting as a direct source of food. Many foliage active invertebrates (herbivores, predators, parasitoids) may shelter beneath the bark. The main insects that feed on bark are bark beetles and ambrosia beetles that leave carvings, scribbles or galleries on the wood beneath the bark (New 1988).

Insects that feed on the wood of the living tree are not as commonly seen because of their habitat. They are generally the immature stages of longicorn (in branches and trunk) and buprestid beetles (in twigs and branches) or cossid and hepialid moths. They bore through the timber, leaving galleries that can be used by fungal and detritus feeders. The larvae of longicorn and buprestid beetles can be parasitised by ichneumonid and braconid wasps or preyed on by clerid and cucujid beetles. Root feeders include the larvae of scarab beetles, such as *Heteronyx* and *Anoplognathus*, and of the giant ghost moth *Trictena atripalpis*. The ends of the empty brown pupal cases of the latter are often found protruding from the ground beneath the canopy.

Species that feed on other invertebrates

These can be divided into two groups: predators and parasitoids. The main insect predators in the canopy include: cantharid beetles, mantids and neuropterans (which use mandibles to chew their prey), asilid flies and reduviid bugs (which use stylet-like mouthparts). Spiders are abundant under bark, particularly *Clubiona* spp. (Clubionidae), and various jumping spiders (Salticidae). White-tailed spiders, *Lampona cylindrata* (Lamponidae) are common, and are thought to prey on the numerous sac spiders (Brunet 1994). Family groups of the social huntsman, *Delena sp.* (Sparassidae) are found under larger sheets of bark. There are certain groups of carabid beetle that rely on the subcortical habitat provided by the bark of River Red Gums (Baehr 1990), such as *Sphallomorpha* sp., which is believed to prey on ants moving up and down the trunk (Matthews 1980). Other non-insect predators include: pseudoscorpions, the scorpion *Lychas marmoreus* and centipedes. Many predators are highly mobile and can move freely within and between trees.

The Gumleaf Skeletoniser, is a good example of how much diversity can be associated with an individual species. Austin and Allen (1989) recorded 22 parasitoid species supported by the immature stages of the Gumleaf Skeletoniser. The eggs of the Gumleaf Skeletoniser may be parasitised by a small wasp, *Trichogramma* sp. There may be egg predators such as the predatory mite *Microsmaris goannae* (Erythraeidae). There are larval parasitoids such as ichneumonid and chalcid wasps and tachinid flies (Campbell 1962). To complete the complex, there could also be pupal parasitoids such as the chalcid wasp *Brachymeria rubripes*.

Other invertebrates

The remainder of the invertebrates include species that scavenge upon detritus, fungal feeders (such as booklice), foragers (e.g. ants such as *Crematogaster* sp. seeking the honeydew exudations of sap-sucking insects or nectar), and accidental

visitors (species that use the tree for shelter, such as adult stages of aquatic insects). Some invertebrates also use microhabitat features, such as bird nests and tree hollows. Bird nests provide shelter for beetles, flies, thrips and moths. There are ectoparasites such as ticks and lice associated with the vertebrates.

River Red Gums can have parasitic mistletoe plants on them. One of the interesting associations is the feeding on mistletoe by larvae of the lycaenid butterfly, *Ogyris olane*. These caterpillars are attended by ant species from genera such as *Iridomyrmex*, *Camponotus*, *Crematogaster*, *Monomorium*, *Podomyrma*, *Ochetellus*, *Anonychomyrma* and *Froggattella* (Eastwood and Fraser 1999). Many of these ant species have ground-layer nests, so their movement between the nest and the canopy is an important link between these two strata.

Invertebrates of the ground and soil layers

The diversity seen in the arboreal fauna extends to forest-floor invertebrate assemblages. Although the ground layer is not as rich in herbivorous species as the canopy, there are many species of more mobile herbivores, such as grasshoppers, as well as the subterranean root feeders mentioned previously. The ground layer has many microhabitat features that provide habitat for invertebrates. These include coarse woody debris, logs, and rocks. Some of these can be microcosms of their own, with a diverse fauna, but very different compared to the canopy fauna. There are more detritivores, scavengers, seed removers and predators active on the ground.

Fallen leaves, twigs and bark form a layer of organic litter on the forest floor. Although the litter layer in River Red Gum forest is not as deep as in wetter forests (Glazebrook and Robertson 1999), the decaying organic matter is still an important resource to many invertebrates. Many small beetles, such as silvanids, feed on the moulds growing on the litter (Matthews 1992).

Moths in families such as the oechophorids have specialised to feed on dead leaves, thus forming an important first step in the recycling process. There are numerous other detritivores, such as cockroaches and flies, as well as a very rich micro-invertebrate fauna dominated by mites and springtails.

Many species of ants nest underground or in logs, so their foraging activity is greater within this stratum. Ants are a major scavenging and predatory group, but some species are also important seed removers.

The role of ants in seed dispersal is likely to be relatively limited in River Red Gum forest because these forests are largely devoid of the shrubby understorey plants, such as *Acacia* spp., which typically have seeds adapted to dispersal by ants. Instead, the main seeds available would be those of River Red Gums and grasses. The greenhead ant, *Rhytidoponera metallica*, one of the most commonly trapped ants in River Red Gum forest, is recognized as an important seed remover in other dry sclerophyll forests (Drake 1981, Hughes and Westoby 1992). Seeds of shrubs adapted to dispersal by ants tend to have hard coatings that are not penetrated by the mandibles of *R. metallica* (Rodgerson 1998). In contrast, Drake (1981) identified *Eucalyptus* spp. seeds with relatively weak coats as being vulnerable to being eaten by *R. metallica*. Thus, the role of ants in River Red Gum forest may be one of seed eaters rather than seed dispersers.

Given the abundance of logs in River Red Gum forests, wood feeding invertebrates are not as common as might be expected. The reasons for this are discussed in Mac Nally *et al.* (2002). In areas that do not flood regularly, termites (*Coptotermes* sp.) are very abundant in fallen timber. Saproxylic beetles found in River Red Gum forest include *Xylion* spp. (Bostrichidae), which bore into the sapwood (CSIRO 1991). Like bark, logs provide shelter, rather than a direct food source, to numerous species. Many ants, including *Iridomyrmex* spp. and *Monomorium* spp., nest in rotting logs.

The subterranean stratum is home to many detritivores, predators, and immature stages of canopy species. The soil species perform several important functions, including burrowing (which assists soil aeration and water percolation) and mixing of decomposing organic matter. The important groups of soil animals include earthworms, spiders, beetle larvae and moth larvae. Living in a burrow potentially confers an advantage in a semi-arid environment, because temperature and humidity tend to be moderated in the burrow.

However, it is likely that flooding prevents burrowing taxa obtaining great diversity in River Red Gum forest. The burrowing wolf spider *Lycosa leuckartii* is found in relatively open areas that flood infrequently. The beetle *Clivina quadratifrons* (Carabidae) is captured in pitfall traps in damp areas. Its powerful forelegs are used for burrowing in sand (Matthews 1980).

Guilds

Mac Nally *et al.* (2002) and Yen *et al.* (2002) emphasize the sheer diversity of invertebrates found in River Red Gum forest. The composition of invertebrate assemblages is not static, but varies both spatially and temporally. Yen *et al.* (2002) found that there was considerable seasonal turnover of species on two individual trees located in close proximity to each other. While acknowledging the limitations of pitfall trapping, Mac Nally *et al.* (2002) found the composition of ground-dwelling invertebrate assemblages to vary between seasons and years, as well as in response to forest-floor characteristics. It is most likely that there is considerable species turnover associated with time (day/night, seasonal), habitat condition (tree age, tree flowering, soil moisture, organic litter loads on forest floor), in space (both on highly-localized and broader scales e.g. between individual trees, and between trees in different geographical locations), environmental change (floods, drought) and anthropogenic factors (clearing, grazing, fragmentation, inappropriate fire).

Yen *et al.* (2002) identified the canopy invertebrates trapped, to species using the usual taxonomic characters that separate them at the class, order, family and species levels. However, with such a large number of invertebrate species and with changes in the composition of the fauna, it is difficult to describe what each invertebrate species is doing in River Red Gum forests. This can be overcome to a certain extent by assessing the ecological functioning of the invertebrates. As many closely related species fulfill similar ecological roles, invertebrates can be classified according to guilds as defined by Root (1967): 'groups of species that exploit the same class of environmental resources in a similar way.' Moran and Southwood (1982) developed a guild classification for arboreal insects in the United Kingdom. The major guilds that they defined are (1) phytophages (plant feeders), divided into (1a) chewers and (1b) sap-suckers; (2) epiphytic fauna; (3) scavenging fauna (excluding ants, but including nectarivores); (4) predators, divided into (4a) insect predators and (4b) other predators (excluding ants); (5) parasitoids; (6) ants; and (7) tourists. This idea has been extended to arboreal invertebrates in Borneo (Stork 1987) and Australia (Yen 1989; Abbott *et al.* 1992; Peters *et al.* 2001), although Abbott *et al.* (1992) and Peters *et al.* (2001) modified the guild definitions to suit their particular studies. The use of guilds permits examination of how groups of animals, not necessarily taxonomically related, utilise a resource. For example, a possum that chews the leaves of a particular species of eucalypt may be placed in the same guild as a leaf chewing species of beetle. A particular species can change guilds in different life cycle stages. For example, the larvae of buprestid beetles feed on wood in the trunk (guild 1a), while the adults feed on flowers of the tree (guild 3).

Invertebrate response to inundation

Under natural conditions, River Red Gum forests are characterized by frequent flooding, with extensive areas of forest inundated for prolonged periods. Those invertebrates usually found on the forest floor must either move to higher ground or ascend the trunks and/or canopy of River Red Gums. Thus, ground-dwelling guilds in River Red Gum forest are expected to display relative niche plasticity and high mobility compared to their counterparts in less variable habitats. Regulation of the Murray River has substantially reduced the frequency and extent of flooding. Flood mitigation potentially alters the structure of ground-dwelling invertebrate guilds, allowing species not adapted to inundation to invade. In addition, many species regarded as canopy inhabitants spend some part of their life cycle on the forest floor, and hence are affected by alterations in flood regime. The next section of this paper examines how changes created by flood reduction ramify throughout all the guilds, demonstrating that various guilds are profoundly interconnected elements of a single ecosystem.

In spring/summer 2000 the Barmah Forest experienced major flooding for the first time in several years. Immediately following the recession of floodwaters, we sampled ground-dwelling invertebrates at different localities throughout the forest that had been subject to inundation of varying extents. The fauna on sites that had been extensively flooded was very different from the fauna of sites that experienced moderate or minor/no flooding. Predatory carabids (ground beetles) comprised only 4% of the beetle fauna trapped on sites which experienced minor or no flooding, compared with 63% on sites which experienced extensive flooding. Similarly, numbers of wolf spiders (Lycosidae) increased dramatically in areas that had recently been inundated for prolonged periods. Wolf spiders and carabid beetles comprise a guild of ground-dwelling, generalist predators. The dominance of this guild immediately following emersion is likely to reflect an increase in both live prey and carrion availability resulting from aquatic taxa becoming stranded by receding floodwaters. Many carabids are adapted to hunt in the riparian zone. For example, *Catadromus lacordairei*, a common species on flood-prone sites, has been recorded preying upon frogs (Littlejohn and Wainer 1978). Several of the dominant wolf-spider species trapped on sites soon after floodwaters receded also are associated with the edge of waterways, such as *Artoria howquaensis* (Framenau submitted).

In order to exploit this short-term increase in prey availability, wolf spiders and carabid beetles must be able to colonize areas rapidly as floodwaters recede. All carabids captured in areas that experienced extensive flooding were fully winged, and hence potentially capable of quickly dispersing into new areas by flight. However, vertical migration, onto tree trunks, or into the canopy, also represents an important flood-survival strategy for wolf spiders and carabids. We trapped invertebrates on tree trunks in both flooded and dry areas of forest. During periods when the forest floor was inundated, searching under sheets of bark on trees standing in floodwater revealed high numbers of invertebrates. In addition to the usual subcortical fauna, such as pancake spiders (*Hemicloea* spp.) and sac spiders (*Clubiona* spp.), specimens of a number of species commonly trapped on the ground in newly emersed areas were collected, including small wolf spiders (e.g. *Artoria howquaensis*) and carabids (e.g. *Catadromus lacordairei*). Thus, many species that are typically thought of as ground-dwelling may utilize arboreal habitat when necessary. Since much terrestrial prey must also climb to avoid rising floodwaters, tree trunks potentially provide rich pickings to the generalist-predator guild during the inundation phase. Other generalist predators, such as marbled scorpions, house centipedes, earth centipedes and scolopendrid centipedes are commonly trapped on both the forest floor and on tree trunks in River Red Gum forest.

Ants, as a guild, potentially demonstrate the greatest plasticity in terms of habitat usage in response to flooding. The ground-foraging ant fauna of River Red Gum forest is not particularly diverse, with only about seven species being commonly pitfall trapped in Barmah forest, including: *Iridomyrmex* sp., *Rhytidoponera metallica*, *Camponotus* sp. and *Paratrechina* sp. Although these species usually nest on the ground, or in rotting logs, when the forest floor flooded all common species were found to shift the nest, complete with reproductives, larvae and pupae to under bark on tree trunks. Again, vertical migration enabled rapid recolonisation of areas following the recession of floodwaters. Although ant activity was temporarily reduced by about half in areas that had recently experienced extensive flooding, ants were still pitfall trapped in high numbers on such sites.

Flooding also impacts on other guilds. Inundation produces changes in canopy structure, with increased leaf longevity and size (Stone and Bacon 1995). This potentially impacts on phytophagous guilds. In addition, increased soil moisture resulting from flooding is known to control populations of the Gumleaf Skeletoniser *Uraba lugens* (Campbell 1962). Thus, the effects of flooding are manifold and extend to all areas of River Red Gum forest and to the invertebrates that live there. A guild approach to invertebrates lets us consider the ecological processes in River Red Gum

forest without being overwhelmed by the great biodiversity.

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THE STORY OF THE MURRAY RIVER
By AS Kenyon, Melbourne

Those interested in the Murray River story should read *The Nile of Australia*, by David John Gordon; *Paving the Way*, by Simpson Newlands; *Half-crown Bob*, by Price Warung, and *Knocking About*, by August Pierce.

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A Preliminary Survey of the Arboreal Invertebrate Fauna of Two River Red Gum Trees *Eucalyptus camaldulensis* near the Murray River

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Abstract

In February and October 1999, the canopy and bark invertebrates from two individual River Red Gum *Eucalyptus camaldulensis* trees in the Moira State Forest NSW were collected. A total of 458 morphospecies was collected from the canopy and 69 morphospecies from beneath the bark. In view of the wide distribution of River Red Gum across Australia, this preliminary survey suggests that there is a high level of invertebrate biodiversity associated with this tree species. (*The Victorian Naturalist* **119** (4), 2002, 180-185)

Introduction

Many eucalypt species have a diverse invertebrate fauna, primarily insects, associated with them (Majer *et al.* 1997). There is considerable information available on a few of these insect species, particularly those that have attained pest status, but there have been relatively few studies on the total fauna. One of the common landscape components associated with the Murray River is the River Red Gum *Eucalyptus camaldulensis* Dehnh. A pilot study, in an attempt to document the invertebrate fauna of a single River Red Gum tree, is reported here. There is considerable seasonal variation in the composition of the invertebrate fauna, so the project involved assessing individual trees at different times of the year.

River Red Gum is a widespread species, probably the most widely naturally distributed species of eucalypt across Australia (Chippendale 1988). Invertebrate studies on River Red Gum have involved studies of pest species such as the Gum Leaf Skeletoniser Moth *Uraba lugens* (Campbell 1962) and psyllid bugs (Collett 2001) to estimates of the amount of insect herbivory on foliage (Stone and Bacon 1994). There are no published studies on the composition of the arboreal invertebrate fauna associated with this species.

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Methods

Field work was conducted in the Moira State Forest (off Coolamon Road), Riverina Region, New South Wales (35°52'46" S 144°55'36" E). Sampling was undertaken on two occasions: 8-10 February 1999 and 6-7 October 1999. In February, a River Red Gum was selected, sampled and then felled to take foliage and wood samples. In October, the invertebrate fauna of a nearby tree was sampled. This tree was not felled for foliage and wood samples.

Arboreal invertebrates

Arboreal invertebrates were collected by spraying the canopy with synthetic pyrethroid Reslin® (manufactured by Wellcome) diluted 1:40 with water. The insecticide was applied with an engine driven spraying machine (Stihl® SG17 Electronic backpack sprayer) that dispels droplets of insecticide. The operator was elevated to a height of up to 15 m with a cherry picker. Spraying was conducted early in the morning (about 0700) in order to utilise rising warm air currents. Spraying the whole tree took about one hour.

Pyrethroid insecticides work as knockdown insecticides; insects succumb to the insecticide after contact. The active life of the insecticide is measured in terms of a few seconds after exposure to sunlight.

The sprayed invertebrates fell from the canopy, and were collected by placing a continuous layer of plastic sheeting beneath the canopy. The invertebrates were left to fall for an hour after cessation of spraying, and then the invertebrates on

the sheets were collected by forceps or paint brushes. This continued for 4 hours after spraying, after which there were no more invertebrates falling on to the sheets.

The first tree was sprayed in fine weather on 9 February 1999. A tree approximately 23 m in height, single trunk, with a good head of foliage was used. One of the conditions for the permit was that the tree was not very old (less than 1.5 m dbh), did not have tree holes or pipes, and was not of Aboriginal cultural significance. The tree had only one mistletoe plant. The tree was estimated to be about 80 years old by New South Wales Forest Commission staff.

A similar sized tree was sprayed on 7 October 1999 using the same regime. This tree was located approximately 100 m from the February tree.

Bark invertebrates

Invertebrates dwelling beneath the bark were collected by direct searching before spraying. The bark was peeled off from ground level to a height accessible with a step ladder (about 3-4 m). Invertebrates were collected with forceps or paint brushes.

Invertebrates from other microhabitats

The leaf litter and woody debris beneath the canopy of the tree was raked over and invertebrates were collected by forceps before spraying. Two samples of litter, each from ground area of approximately 1 × 1 m, were brought back to the laboratory for extraction in Tullgren Funnels (heat funnels). Samples were left in the Tullgren Funnels for 5 days. The soil directly beneath the litter searched was raked and dug up to a depth of 10 cm for invertebrates. Invertebrates were collected using forceps. Only a small number of invertebrates were collected in February using this technique, so it was not repeated in October. Several samples of timber (trunk and branches) were taken back to the laboratory to see if any invertebrates emerged. The timber was kept for 12 months. Leaves were also kept, but little emerged from these samples.

Identification

All specimens were sorted initially to a higher taxonomic level – generally to the ordinal level. However, millipedes and centipedes were identified only to Class, and Hymenoptera was divided into ants and non-ants (mainly wasps). Specimens were then identified to the morphospecies level. In some groups (Coleoptera, Neuroptera, Diptera and Lepidoptera), immature stages were treated as separate from adults.

Specimen sorting and storage

All material was labeled and stored either in 70% ethanol or pinned. Specimens are to be initially used as part of a Museum Victoria exhibition on River Red Gum biodiversity, after which it will be deposited into the Museum collection.

Results and discussion

Total invertebrate fauna

A total of 8456 invertebrates, identified into 547 morphospecies from 24 orders, was collected from the two trees with all the collecting techniques (Yen 2000). Results presented in detail here are only the canopy and bark samples because the other microenvironments were probably undersampled. The identification of specimens to morphospecies may result in the double counting of certain species if (1) immature and adult stages of the same species are considered different morphospecies, or (2) if there is marked sexual dimorphism which has not been considered.

The potential effects of distinguishing immature and adults as different morphospecies can be estimated when the number of morphospecies collected from the canopy is considered (Table 1). The spraying resulted in 458 morphospecies, of which 31 were larval morphospecies. Consequently, 31/458 (6.8%) of morphospecies, were larvae. When the number of individuals is considered, 316/6666 (4.7%) were larvae. For the bark fauna, the percentages are 11.6% (8/69) for morphospecies or 0.7% (8/1175) for individuals (Table 1).

Canopy invertebrate fauna

In February 1999, a total of 297 morphospecies, represented by 4092 individuals from 19 orders, was collected from the canopy spraying, and 260 morphospecies (2574 individuals) were collected in October. A total of 458 morphospecies (6666 individuals) was obtained from the two trees (Table 1).

The most dominant invertebrate groups in terms of number of morphospecies were

Table 1. Numbers of species and individuals of invertebrates from River Red Gum canopy and bark.

Order	Canopy						Bark					
	February		October		Total		February		October		Total	
	Species	Individuals	Species	Individuals	Species	Individuals	Species	Individuals	Species	Individuals	Species	Individuals
Araneae	24	154	28	75	40	229	6	18	15	34	17	52
Scorpionida	0	0	0	0	0	0	0	0	1	24	1	24
Pseudoscorpionida	1	21	2	12	2	33	1	1	1	58	1	59
Acarina	3	230	1	19	4	249	2	7	6	22	7	29
Chilopoda	0	0	0	0	0	0	0	0	1	1	1	1
Diplopoda	0	0	0	0	0	0	0	0	2	303	2	303
Collembola	1	1	1	1	2	2	0	0	3	13	3	13
Thysanura	0	0	1	2	1	2	0	0	0	0	0	0
Odonata	3	15	0	0	3	15	0	0	0	0	0	0
Blattodea	2	6	1	2	3	8	0	0	0	0	0	0
Mantodea	1	1	0	0	1	1	0	0	0	0	0	0
Orthoptera	5	25	3	15	7	40	0	0	2	2	2	2
Phasmatodea	1	1	0	0	1	1	0	0	0	0	0	0
Psocoptera	0	0	2	32	2	32	0	0	1	3	1	3
Hemiptera	68	646	27	474	87	1120	2	3	8	15	10	18
Thysanoptera	4	346	3	23	5	369	1	1	0	0	1	1
Neuroptera	2	2	2	4	3	6	0	0	0	0	0	0
Neuroptera larvae	0	0	1	2	1	2	0	0	0	0	0	0
Coleoptera	45	625	53	765	82	1390	1	1	5	9	6	10
Coleoptera larvae	4	54	8	172	10	226	0	0	5	5	5	5
Strepsiptera	1	3	0	0	1	3	0	0	0	0	0	0
Diptera	54	560	56	515	75	1075	0	0	0	0	0	0
Diptera larvae	1	9	0	0	1	9	0	0	0	0	0	0
Lepidoptera	1	7	1	46	1	53	0	0	0	0	0	0
Lepidoptera larvae	10	53	12	26	19	79	0	0	3	3	3	3
Hymenoptera - ants	12	1201	8	115	15	1316	4	33	6	618	8	651
Hymenoptera - other	54	132	50	274	92	406	0	0	1	1	1	1
Total	**297**	**4092**	**260**	**2574**	**458**	**6666**	**17**	**64**	**60**	**1111**	**69**	**1175**

Table 2. Number of species of invertebrates collected only in February, only in October and in both February and October (total).

Order	Canopy			Bark		
	February	October	Total	February	October	Total
Araneae	12	16	12	2	11	4
Scorpionida	0	0	0	0	1	0
Pseudoscorpionida	0	1	1	0	0	1
Acarina	3	1	0	1	5	1
Chilopoda	0	0	0	0	1	0
Diplopoda	0	0	0	0	2	0
Collembola	1	1	0	0	3	0
Thysanura	0	1	0	0	0	0
Odonata	3	0	0	0	0	0
Blattodea	2	1	0	0	0	0
Mantodea	1	0	0	0	0	0
Orthoptera	4	2	1	0	2	0
Phasmatodea	1	0	0	0	0	0
Psocoptera	0	2	0	0	1	0
Hemiptera	59	19	9	2	8	0
Thysanoptera	2	1	2	1	0	0
Neuroptera	1	1	1	0	0	0
Neuroptera larvae	0	1	0	0	0	0
Coleoptera	29	37	16	1	5	0
Coleoptera larvae	2	6	2	0	5	0
Strepsiptera	1	0	0	0	0	0
Diptera	29	21	25	0	0	0
Diptera larvae	1	0	0	0	0	0
Lepidoptera	0	0	1	0	0	0
Lepidoptera larvae	7	9	3	0	3	0
Hymenoptera - ants	7	3	5	2	4	2
Hymenoptera - other	42	38	12	0	1	0
Total	**207**	**161**	**90**	**9**	**52**	**8**

bugs (Hemiptera), flies (Diptera), wasps (Hymenoptera), beetles (Coleoptera), spiders (Araneae), and ants (Hymenoptera) in February (Table 1), and in October the descending order of dominance was beetles, flies, wasps, spiders and bugs (Table 1).

In terms of numbers of individuals, the most dominant groups were ants, beetles, bugs, flies, thrips (Thysanoptera) and mites (Acarina) in February (Table 1), while beetles, flies, bugs and wasps dominated the October sample (Table 1). The reduction in numbers of ants between February and October was most marked.

Bark invertebrate fauna

In February 1999, a total of 17 morphospecies, represented by 64 individuals from 14 orders, was collected from beneath the bark, and 60 morphospecies (1111 individuals) were collected in October. A total of 69 morphospecies (1175 individuals) was obtained from the two trees (Table 1).

At the morphospecies level, the dominant groups were spiders and ants in February, and spiders, bugs, mites, beetles, and ants in October (Table 1).

When the number of individuals under bark is considered, the dominant groups in February were ants, spiders and mites (Table 1). In October, the ants still dominated the bark fauna, followed by millipedes (Diplopoda) and pseudoscorpions (Pseudoscorpionida) (Table 1). It is interesting to note that only seven invertebrate orders were collected under bark in February compared to 14 orders in October.

Differences between February and October

Of the 458 morphospecies collected from the canopy, 207 were collected only in February, 161 only in October, and 90 (19.7% of morphospecies) were collected in both February and October. Of the 69 morphospecies collected from beneath bark, nine were collected only in February, 52 only in October, and eight (11.6% of morphospecies) were collected in both February and October (Table 2).

Table 3. Number of species only on canopy or on bark, or on both canopy and bark (C+B).

Order	Canopy	Bark	C +B
Araneae	33	10	7
Scorpionida	0	1	0
Pseudoscorpionida	1	0	1
Acarina	1	4	3
Chilopoda	0	1	0
Diplopoda	0	2	0
Collembola	1	2	1
Thysanura	1	0	0
Odonata	3	0	0
Blattodea	3	0	0
Mantodea	1	0	0
Orthoptera	6	1	1
Phasmatodea	1	0	0
Psocoptera	2	1	0
Hemiptera	81	4	6
Thysanoptera	4	0	1
Neuroptera	3	0	0
Neuroptera larvae	1	0	0
Coleoptera	80	5	2
Coleoptera larvae	9	4	1
Strepsiptera	1	0	0
Diptera	85	0	0
Diptera larvae	1	0	0
Lepidoptera	1	0	0
Lepidoptera larvae	18	1	0
Hymenoptera - ants	7	0	8
Hymenoptera - other	92	1	0
Total	**436**	**37**	**31**

The total numbers of individuals collected from the canopy in February was 4092 compared to 2574 in October (Table 1). The increase was due to more spiders (154 in February: 75 in October), mites (230:19), bugs (646:474) and significantly, ants (1201:115). In contrast, there were more beetles (625:765) and non-ant Hymenoptera (132:274) in October. For the fauna beneath bark, the number of individuals in October was 1111 compared to 64 in February. Practically all invertebrate orders had more individuals beneath bark in October, and the major components were spiders, scorpions, pseudoscorpions, millipedes and ants.

These seasonal differences may be attributable to seasonal activity patterns in the different invertebrate groups. Some may simply have been more active at one time of the year, while others may have been utilising different microhabitats or had different patterns of seasonal development. Some species may be inhabiting the soil or litter layers during one season and move into the bark and canopy in another; this could occur for groups such as scorpions and ants.

Links between canopy and bark

A total of 436 morphospecies were collected only from spraying the canopy, 37 morphospecies collected only from beneath bark, while 31 morphospecies were found in both canopy and bark samples (Table 3). However, the canopy spraying could have sampled bark invertebrates from further up the tree.

River Red Gum invertebrate diversity

Stone and Bacon (1994) studied insect herbivores in River Red Gum forests in the nearby Gulpa Island State Forest (NSW). They found 49 species of phytophagous insects in the canopy, and the dominant orders were the Phasmatodea, Hemiptera, Thysanoptera, Coleoptera, Diptera, Lepidoptera and Hymenoptera. In our study, Phasmatodea and Lepidoptera occurred in very low numbers.

Majer *et al.* (2000) used canopy knockdown on four species of eucalypts: *Eucalyptus creba* and *E. moluccana* in eastern Australia and *E. marginata* and *E. calophylla* in western Australia. They found 27 orders of invertebrates: 967 morphospecies in eastern Australia and 687 morphospecies in western Australia. Their method differed in that their sampling regime involved spraying 10 trees of each species and collections were made with 10 × 0.5 m^2 funnel-shaped nets under each tree. The procedure was repeated seasonally for four seasons. The larger number of morphospecies collected by Majer *et al.* (2000) may be attributable to the larger number of eucalypt species in their study, more intensive seasonal sampling, and geographical differences in the fauna.

Eucalyptus camaldulensis is the most widely naturally-occurring species of eucalypt in Australia. Our study involved two individual trees in one locality, and even allowing for over-estimation of number of morphospecies by distinguishing between immature stages and adults, some 458 morphospecies were collected from the canopy and 69 morphospecies from beneath the bark. We could expect this number to increase substantially if the study was repeated to allow for species turnover asso-

ciated with seasonal changes, changes in the state of the tree (e.g. flowering), differences between individual trees in the same area, differences between geographical locations, differences between extreme environments (temperate versus arid), and allowing for the fact that the fauna dwelling within the timber is under-represented.

Since European settlement, River Red Gum woodlands have undergone a range of environmental changes such as timber harvesting, fragmentation, and altered hydrology regimes. If the effects of these and other changes on the invertebrate fauna of River Red Gums is to be understood, basic information on the composition of the invertebrates associated with River Red Gums over a broad range is required.

Acknowledgements
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The Murray River in *The Victorian Naturalist*

NOTES ON A COLLECTING TRIP TO THE MURRAY AND LODDON RIVERS

By C French, Jun.
Read before Field Naturalists' Club of Victoria, 11 January 1897

4th November. — Drove to Salt Lake and caught a couple of Lizards—a Monitor and a lace Lizard, or Iguana; on the latter were noticed a great many ticks similar to the ones found on Opposums and Native Bears. Bee-eaters were seen in numbers, but they were only just commencing to tunnel, and none had eggs. Orange-fronted Ephthianuras were seen in fairly numerous quantities, but though some hours were spent searching round the edges of this lake amongst the Salicornia bushes, only one nest was taken… Much to our gratification a nest of Chestnut-eared Finch was found underneath and attached to a Brown Hawk's nest.

10th November — crossed into New South Wales to work some swampy country … birds were numerous, amongst which the following were conspicuous: Painted and New Holland Snipe, Dottrel (of four species), Rails (of two species), Bee-eaters, Ibis, Black-tailed Tribonyx, &c.

Altogether upwards of 100 different species of birds were noticed. Plants to the number of about seventy were collected, in flower, which was a very fair collection, considering the dry season. Beetles were fairly numerous, about eighty species being collected. Appended are lists of the specimens obtained on our excursions.

From *The Victorian Naturalist* **XIII** (10), January 1897, pp 127-134.

Aquatic Macroinvertebrates of the Murray River

Phillip J Suter[1] and John H Hawking[2]

This article is dedicated to the memory of Prof WD (Bill) Williams (1936-2002) whose early books on the aquatic invertebrates of Australian inland waters stimulated interest and research on the ecology of these important groups.

Abstract

The aquatic macroinvertebrate fauna of the Murray River is presented based on surveys and scientific literature. Insects dominate the aquatic macroinvertebrate fauna but the non-insect groups such as the crustaceans, molluscs, worms and other primitive classes are also well represented. The distribution of the fauna is discussed in relation to the four physical and biological zones of the river; the Headwater, Riverine, Mallee and Lower Murray tracts. The biology and ecology of many groups is documented and, where possible, the impacts of human influences on the invertebrates of the Murray River are given. (*The Victorian Naturalist* **119** (4), 2002, 186-200)

Introduction

The aquatic invertebrates are to a certain extent the forgotten fauna of the Murray River. With the exception of the Murray River crayfish and of course the nuisance insects such as mosquitoes the aquatic invertebrates come a distant second to the more obvious aquatic icons such as Murray Cod, Golden Perch, Macquarie Perch and other native fish. However, the aquatic invertebrate fauna are an important component of a healthy functioning river and should not be viewed as just a part of the food supply for fish. The aquatic macroinvertebrates are an essential component of a functioning aquatic ecosystem. They are primarily decomposers with herbivores and predators making up the functioning feeding groups (Bolton and Brock 1999). Their feeding activities mobilise carbon and energy from plants through to the higher aquatic orders. In addition the aquatic macroinvertebrates have been used successfully as indicators of water quality and river condition (Norris *et al.* 2001).

The aquatic macroinvertebrate fauna of the Murray River as a whole were not examined systematically until 1980 when the then River Murray Commission commenced their biological monitoring programme which is still ongoing today. Over 430 macroinvertebrates taxa were recorded from the Murray River between Jingellic and Lake Alexandrina during 1980-1985 (Bennison *et al.* 1989). Insects dominated the aquatic invertebrates with crustaceans, molluscs and worms also well represented. Sources of information for this paper include (Bennison *et al.* 1989; Boulton and Lloyd 1991; Suter *et al.* 1993) and personal observations by the authors. Throughout the paper reference will be made to the highly modified flow regimes caused by the consumptive use of water from the river. This has undoubtedly influenced the macroinvertebrate composition and distribution (Geddes 1990; Walker 1990), but detailed discussion of these effects is beyond the scope of this paper. An excellent presentation of the hydrological and geomorphological structural changes to the river can be found in Thoms *et al.* (2000).

The Murray River physically and biologically can be divided into four major zones or tracts (Bennison *et al.* 1989; Thoms *et al.* 2000) (Fig. 1);

- the Headwaters tract reaches from the Murray's source to Albury. The gradient of the river is steep and the streams are dominated by cobble, boulder and sand substrates with little organic material. This zone includes the alpine areas down to the foothills (Fig. 2);
- the Riverine tract reaches from Albury to the junction of the Edwards River. The gradient is low, the substrate is dominated by sand and silt with moderate levels of organic material and the river flows across

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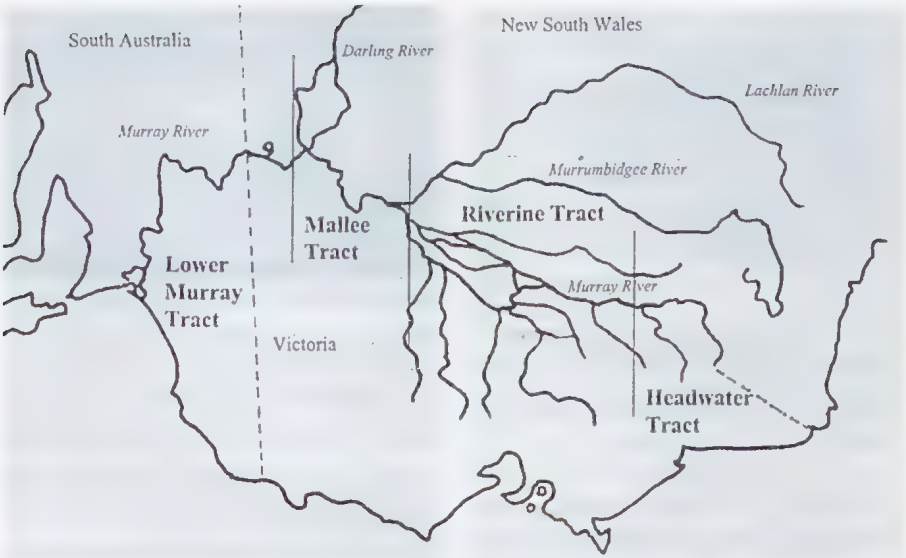

Fig. 1. The four physical and biological tracts of the Murray River.

a broad floodplain and is multi-channelled with extensive floodplain wetlands;

- the Mallee tract reaches from the Edwards junction to the Darling junction. The low gradient continues, and the substrate is sand and silt with moderate levels of organic material. Throughout this tract the river flows along a single narrow watercourse; and
- the Lower Murray tract reaches downstream of the Darling junction to the Murray mouth (Fig. 3). The river gradient is the lowest in this tract, the substrate is dominated by sand and silt with moderate levels of organic material, and the river is now highly regulated with locks and weirs which have altered the characteristics of the river from lotic to lentic.

This paper provides an overview of the aquatic macroinvertebrate fauna of the Murray River, including both the main channel and the floodplain wetlands that together constitute the ecological component and integrity of the river, and relates their distribution to these zones.

Cnidaria

The Cnidaria is represented in the Murray River by at least three genera, two hydrozoans (*Hydra* and *Cordylophora*) and the freshwater jellyfish *Craspedacusta sowerbyi*. The solitary hydroid *Hydra* is found in the Riverine, Mallee and Lower Murray Tracts but the colonial hydroid *Cordylophora* appears restricted to the Lower Murray Tract (Bennison *et al.*

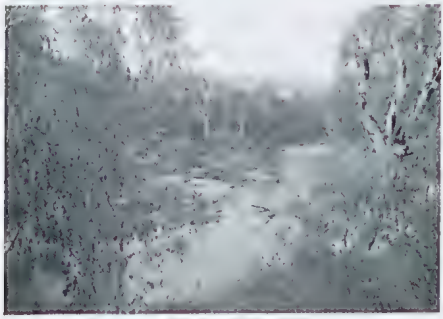

Fig. 2. Headwater tract near Jingellic.

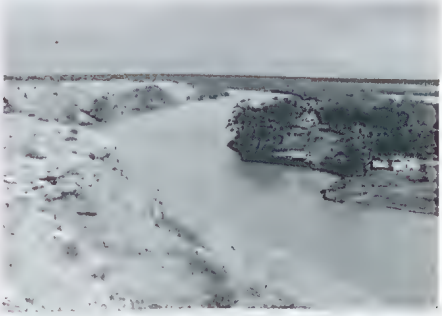

Fig. 3. Lower Murray tract in South Australia.

1989). Both these genera occur on logs and other such stable substrates. Their distribution may be greater than the artificial substrate data suggests but other sampling methods used in rivers may limit the adequacy of collections.

The freshwater jellyfish *Craspedacusta sowerbyi* has been recorded in the Hume reservoir but it is rarely seen because it is small (25 mm diameter) and almost transparent. This limited distribution in the Murray system may be a product of sampling effort. Little is known about this species although Williams (1980) recorded that it is usually found floating near the surface of large freshwater lakes and reservoirs.

Turbellaria (Flatworms)

Flatworms are recorded throughout the river from the headwaters to Lake Alexandrina. In the headwaters *Spathula* sp., a very dark animal, is commonly found on rocks. Ball (1977) recorded that all species of *Spathula* are found in cool, well oxygenated mountain water. *Cura pingus* is a lowland species and has been recorded from above Lake Hume to the end of the Murray River. The taxonomy of this group is limited and formal identification requires serial sectioning of properly preserved animals (St Clair *et al.* 1999). It is highly likely that there are more species than these two in the Murray, particularly in the Headwater tract (St Clair *et al.* 1999).

Temnocephalidea

The temnocephalans are small oval-shaped animals with 2-6 apical tentacles. The temnocephalans are ectosymbionts on freshwater crayfish. Some species live on the carapace of these large crustaceans and others in the gill chamber where they feed on small insect larvae, rotifers and nematodes, and algae (Williams 1980). An individual crayfish can often have multiple species on its body. A study by Cannon and Sewell (1994) suggested that each crayfish species had a distinct temnocephalan fauna associated with it. The taxonomy of this group is currently being revised. At least nine species have been recorded from the Murray River with *Temnocephala caeca* in the Headwater tract and *Temnocephala chaeropsis* mainly from the Mallee and Lower River tracts.

Fig. 4. Tubificid worm *Branchiura sowerbyi*.

Nematomorpha (Horsehair worms)

Adult horsehair worms, genus *Gordius*, have been recorded in pools in the Headwater and Riverine tracts of the Murray River down to Corowa. The larvae and juveniles are parasitic in terrestrial invertebrates (insects) where they encyst after being eaten and later break out of the host as an adult when the host is near water (Williams 1980).

Annelida (Worms and leeches)

The oligochaetes (segmented worms) are common throughout the Riverine, Mallee and Lower Murray tracts. Worms do occur in the Headwater tract, but numbers are generally low. Bennison *et al.* (1989) only identified the worms as non-tubifids and tubificids. The non-tubificid worms were abundant in the Riverine and Mallee tracts particularly in the depositional zones where organic material accumulates. The tubificid worms were low in abundance along the length of the river suggesting very low levels of organic pollution. One of the most noticeable tubificid worms is *Branchiura sowerbyi*, a distinctive hairy-gilled worm recognised by the posterior half having conspicuous gills (Fig. 4). It is common but not abundant in all tracts downstream of Albury occurring in depositional zones where there is a build up of fine organic material.

The leeches were represented by two families, Glossiphoniidae and Richardsonianidae. The Glossiphoniidae are small translucent leeches that prey on invertebrates particularly freshwater gastropods (Williams 1980) and are low in abundance in the Headwater, Mallee and Lower Murray tracts. The larger Richardsonianidae were rare in the river and were only recorded in the Lower Murray tract.

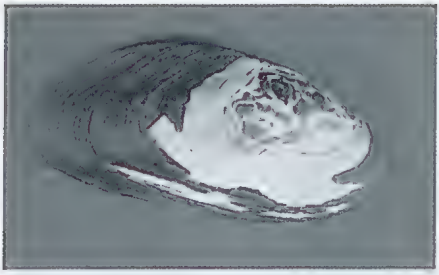

Fig. 5. Murray River Mussel *Alathyria jacksoni.*

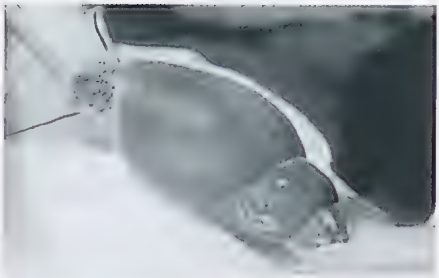

Fig. 6. Gastropod snail.

Mollusca (Snails and mussels)

The molluscs are well represented in the Murray River with 5-10% of the community composition in the main channel of the Headwater tract, but they decline to less than 5% in the Riverine, Mallee and Lower Murray tracts (Bennison *et al.* 1989). The distribution of many species may have changed since regulation of the Murray began in the early 1900s (Sheldon and Walker 1993).

Bivalvia (Mussels, pea-clams)

The small bivalves *Sphaerium* sp., *Pisidium* sp. and *Corbiculina australis* occur in the main channel of the river with *Sphaerium* most abundant above Lake Hume, *Pisidium* in the headwater streams and C. *australis* along the length of the river from the headwaters to Lake Alexandrina.

Two large bivalve molluscs are associated with the Murray River. The common riverine mussel *Alathyria jacksoni* (Fig. 5) occurs in the main stream channel in areas with flow, and the floodplain mussel *Velesunio ambiguus* is found in the slow or still waters of backwaters and billabongs. In the Lower Murray tract the hydrology has been highly modified by the presence of locks and weirs resulting in stationary/slow flowing reaches rather than a natural flowing river. Walker (1990) suggested that this change has provided the opportunity for *Velesunio ambiguus* (the floodplain species) to invade the main channel of the river at the expense of *Alathyria jacksoni* (the riverine species). *Velesunio ambiguus* lives in the calm waters behind the weirs and *A. jacksoni* in the turbulent waters below the weirs (Walker 1990).

A population of a third species of mussel *A. condola* exists below Lake Mulwala. The mussels have a larval stage (glochidia) which is parasitic on fish (Walker 1990) and it is most likely that *A. condola* has colonised the Murray on fish migrating from the Murrumbidgee River via the Mulwala Canal.

Gastropoda (Snails)

About 18 species of gastropod molluscs or snails (Fig. 6) have been recorded from the lower Murray River and were abundant in the first half of the 20th century (Sheldon and Walker 1993). Recent work along the lower reaches suggests that many species have very low abundances or no longer occur (Bennison *et al.* 1989; Boulton and Lloyd 1991; Sheldon and Walker 1993). One such species, *Notopala sublineata hanleyi*, is a live bearing snail that was common from the lower Murray but now appears extinct in the river. However, an extant population was reported by Sheldon and Walker (1993) taking up residence in the Kingston and Loveday irrigation pipelines near Barmera, South Australia. Sheldon and Walker (1993: 298) suggest that 'this is possibly the last surviving population of *N. hanleyi*'. In addition a number of other species of snails have a greater abundance in pipelines than in the lower river, including, *Ferrissia petterdi*, *Gabbia australis*, *Glyptophysa aliciae*, *Thiara balonnensis* and '*Angobia angasi*'. All these species are detritivores feeding on organic and microbial accumulations and the inside of the pipelines provides ideal habitat compared with the highly regulated lower Murray River (Sheldon and Walker 1993). The pipelines provide the variability of wetting and drying that once occurred in the lower Murray, but does not occur now due to regulation. This refuge in the irrigation pipelines is also a nuisance for irrigators as the snails can block sprinklers

and drip irrigation lines. The sculptured snail *Thiara balonnensis* still occurs in the river from Lake Mulwala to South Australia but is now rare in the lower reaches of the river except in the irrigation pipelines. The freshwater limpet *Ferrissia petterdi* is still common throughout the Murray and its flood plain being found in fast flowing waters as well as in billabongs and backwaters.

There are seven species of the family Planorbidae represented along the Murray, with riverine and floodplain species. *Glyptophysa gibbosa, Isidorella hainesii, Glyptophysa aliciae, Bayardella cosmeta* are found mainly in the river, whereas *Gyraulus meridionalis, G. tasmanicus* and *Helicorbis australiensis* are more common in the backwaters and billabongs. The riverine species have helicoil shells (normal coiled snail) and the floodplain species have flat, ammonite-like shells. These snails all graze on aquatic plants. *Glyptophysa gibbosa, Isidorella hainesii, Gyraulus meridionalis, Helicorbis australiensis, Glyptophysa aliciae* and *Bayardella cosmeta*, occur along the length of the Murray whereas *G. tasmanicus* only occurs in streams of the upper Headwater tract. Regulation has been implicated in the loss of aquatic plants in the Murray River (Thoms *et al.* 2000) particularly where there is raised turbidity reducing light availability (Lower Murray tract) and river bank erosion (Riverine, Mallee and Lower Murray tracts). This reduction of aquatic plants in the main channel may also have affected the distribution of the planorbid snails. In floodplain wetlands where the aquatic plants are still abundant the planorbid snails still can be found.

A number of introduced gastropod snails have successfully colonised the Murray River. *Physa acuta*, a snail introduced from Europe or North America, was known from only the lower Murray prior to 1970 (Smith and Kershaw 1979). However, this species has spread the length of the Murray and now competes with the planorbid snails and in many cases has replaced the native species. Bennison *et al.* (1989) recorded the planorbid snails *Isidorella* sp. and *Physastra gibbosa* downstream of the Hume weir until 1980 after which it was replaced by *Physa acuta*. *Potamopyrgus niger* was introduced from New Zealand and occurs in the lower Murray tract. It is possible that this species will also become widespread throughout the Murray and its tributaries.

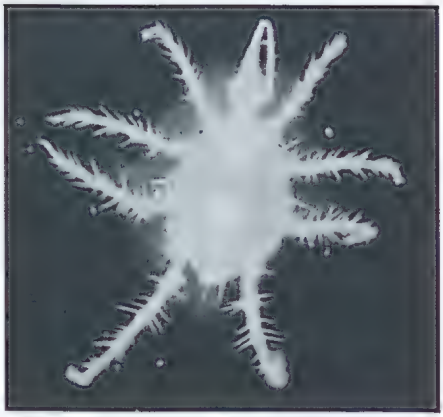

Fig. 7. The water mite *Peza ops.*

Arachnida (Water mites)

Water mites are a common fauna of the Murray River and its floodplain wetlands but are not well documented because they are difficult to identify. Reliable identification of water mites of the Headwater tract has shown that there are representatives of three major groups: Hydracarina, Halacaroidea and Oribatida. The last two groups are few in number with only single species of each group being recorded, whereas the Hydracarina are abundant and diverse. An unknown species of Orabatida is commonly collected from gravel beds in the river. Also commonly collected is the halacaroidean *Peza ops*, a terrestrial-like mite, whose gnathosoma has a long, curved, slender rostrum, with the pedipalps inserted above the rostrum (Fig. 7). The common Hydracarina are *Coaustraliobates, Austroliobates, Killimobates, Flabellifrontipoda, Hydroma* and *Unionicola*. Watermites are also common in floodplain wetlands with over 20 morpho-species recorded from wetlands along the Murray in South Australia (Suter *et al.* 1993).

Water mites have also been found parasitising the freshwater mussels, with six species being associated with *Velesunio ambiguus* and 3 of those with *Alathyria*

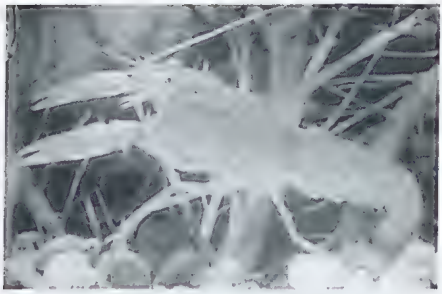

Fig. 8. The Common Yabby *Cherax destructor.*

Fig. 9. The Murray Crayfish *Euastacus armatus.*

jacksoni. Five species of the genus *Unionicola* have only been recorded from the Murray in South Australia. The sixth, *Unionicolopsis opimipalpis*, has been found on *V. ambiguus* collected from the Murray River near Albury (Viets 1980).

Crustacea (Shrimp, yabbies and crabs)

The crustaceans are a major component of the aquatic invertebrate fauna of the Murray River, and are the dominant invertebrate group in the lowland tracts of the river. In the Headwater, Riverine and Mallee tracts the Crustacea represent between 2-5% of the aquatic invertebrate community, but in the Lower Murray tract the proportion of crustaceans increases to 10-15% of the macroinvertebrate community (Bennison *et al.* 1989).

Amphipoda (Sideswimmers, scuds)

The amphipods, side swimmers or scuds, are small fast swimming crustaceans that have a very distinct distribution in the Murray River. Generally they are rarely found in the main channel upstream of the Darling River junction. Amphipods become a major component of the lower river fauna in South Australia with *Austrochiltonia* spp. and two species of gammarid amphipods reaching high abundances downstream of Morgan.

Decapoda (Yabbies, crayfish, shrimps and prawns)

Shrimps and prawns are represented along the Murray River by three species, *Paratya australiensis*, *Macrobrachium australiense* and *Caridina mccullochi*. All three species occur in both the main channel and floodplain wetlands. *Paratya* becomes more abundant in the main channel in the lower sections of the river system and this could be a response to altered flow regime due to the presence of locks and weirs. In contrast, *Macrobrachium* is more prevalent in the foothills of the Headwater tract. *Caridina* is rare at all sites along the river.

The Murray River has two species of freshwater crayfish, the Common Yabby *Cherax destructor* (Fig. 8) and the Murray River Crayfish *Euastacus armatus* (Fig. 9). Both species are omnivores feeding on detritus, algal biofilm and carrion. The yabby is the smaller of the two species (<250 g in weight; Geddes 1990) and is common in billabongs, backwaters and other wetlands on the floodplain. Following floods, numbers can increase rapidly and large numbers are caught from wetlands along the floodplain. *Cherax destructor* now occurs in the main channel of the river in the Lower River tract where the locks and weirs have changed the flow regime from a river to a series of long narrow lakes. The Murray River crayfish is the second largest freshwater crayfish in the world (reaching up to 3 kg in weight; Geddes 1990) second only to the giant freshwater crayfish *Astacopsis gouldi* from Tasmania. It lives in the main channel of the river and tributaries where flow rates are higher. Geddes (1990) noted that *C. destructor* is adapted to slow flowing, warm water and is active in the warmer months (September to May) whereas, *E. armatus* is adapted to cool waters and strong flowing rivers and is active in the cooler months (May to October) when oxygen concentrations are high. The occurrence of the two species in the Murray River follows a similar pattern to the mussels with the riverine species (*E. armatus*) being replaced by the floodplain species (*C. destructor*) in those sections of

the river which are controlled by the locks and weirs. Geddes (1990) suspects that natural populations of *E. armatus* are now extinct in South Australia. The distribution of the Murray River crayfish is also influenced by fishing pressure and habitat modification. Snags in the Murray River provide large stable substrates for macroinvertebrates and both number of species and abundance is higher on snags than on the associated river bed (Lloyd *et al.* 1991). The removal of over 13 million snags from the river (Thoms *et al.* 2000) not only has affected the fish populations but also the macroinvertebrates, and most probably the Murray River crayfish.

The small spider crab *Amarinus lacustris* is commonly found in streams with elevated salinities. This species is only found in the lower Murray downstream of Murray Bridge where it lives in the roots of the willow trees that dominate the riparian zone.

Syncarida

The syncarids are primitive crustaceans that lack a carapace over their thorax and although extinct syncarids were marine inhabitants all living forms are now restricted to fresh waters (Williams 1980). A single specimen of a syncarid crustacean *Koonunga* sp. has been recorded from the Murray River near Albury. Syncarids of this genus are usually associated with deep hyporheic gravels, and so are rarely found in rivers unless washed out during high flows.

Isopoda

Two species of isopod occur in the Murray River, *Heterias pusilla* and *Tachaea picta*. *H. pusilla* is a small isopod which lives in fine organic deposits in the Riverine, Mallee and Lower Murray tracts. They are occasionally recorded from the upper catchment, but they generally are rare. *Tachaea picta* has a more restricted distribution occurring only in the Lower Murray tract downstream of the Darling junction, but rarely downstream of Morgan. The distribution of *Tachaea* is usually restricted to the Darling River where it is parasitic on shrimps and prawns. During Darling River flood, *Tachaea picta* is washed into South Australia and becomes common in the lower Murray River.

Insecta

The insects are the dominant macroinvertebrate fauna in the Murray River representing over 70% of the communities in the main channel and wetlands in all tracts.

Ephemeroptera (Mayflies)

The mayflies are a primitive order of insect with an aquatic nymphal stage and two terrestrial winged stages, the subimago and imago or spinner. They are diverse in the Murray River with over 20 species being recorded along its length but they represent less than 5% of the aquatic community. The number of species present declines along the river's length with approximately 15 species in the Headwater tract, less than ten species at Albury and downstream in the Riverine tract and only four species downstream of the Darling River junction. This reduction in taxa can also be seen at the generic level with Coloburiscidae (*Coloburiscoides*) Oniscigastridae (*Tasmanophlebia*) Baetidae (*Edmundsiops*) Caenidae (*Irpacaenis* and *Tasmanocoenis*) and the Leptophlebiidae (*Atalophlebia, Nousia, Koorrnonga, Ulmerophlebia, Neboissophlebia* and *Austrophlebioides*) common in the Headwater tract. In the Riverine tract downstream of Albury only *Atalophlebia, Neboissophlebia, Edmundsiops, Irpacaenis* and *Tasmanocoenis* are found. *Atalophlebia, Cloeon* and *Tasmanocoenis* are the only genera that occur in the Lower Murray tract. The reduction of taxa may reflect a natural gradient from upland to lowland river conditions as *Coloburiscoides*, *Edmundsiops, Nousia, Koorrnonga, Austrophlebioides* and *Neboissophlebia* all occur in cool, highly oxygenated flowing streams that are usually associated with upland reaches. The genera *Atalophlebia*, *Cloeon* and *Tasmanocoenis* are more commonly associated with warm, slow flowing habitats.

Pardo *et al.* (1998) recorded a decline in mayfly diversity in the Mitta Mitta River downstream of Dartmouth dam (11 species) compared with an unregulated tributary (17 species). There were fewer leptophlebiid mayflies in the regulated com-

pared with the unregulated river. They argued that the pattern of flow and cold water releases in summer in the regulated Mitta Mitta Rivers adversely affected the mayfly community. The relative abundance of nymphs of *Coloburiscoides* was not dramatically affected by the regulated flows (21% in unregulated and 27% in regulated), but *Edmundsiops hickmani* declined from 53% to 13% (Pardo *et al.* 1998). These two species are restricted to the fast flowing mountain streams where they are found on rocks or on logs in the fast flowing water. *Coloburiscoides* wedge their bodies between rocks using the spines on their gills as anchors (Dean and Suter 1996) and use the long hairs on their legs and mouthparts to trap particles of organic material flowing by in the fast flowing water.

The two genera of the Baetidae recorded in the Murray River, *Edmundsiops* and *Cloeon*, occupy the lotic and lentic habitats respectively. *Edmundsiops* is restricted to the upper catchment, whereas *Cloeon* is associated with the lower tracts in stationary waters and wetlands particularly in beds of aquatic plants.

The nymphs of the Oniscigastridae (*Tasmanophlebia*) occur in standing waters and slow flowing reaches of rivers and streams from the mountains to near sea level. They are normally found on sandy substrates (Dean and Suter 1996), but they do not occur downstream of Albury in the Murray.

The caenid mayflies, the smallest mayflies in Australia, are found along the river's length and also in the floodplain habitats. These mayflies are detritivores and live in silt and sand particularly on logs and in leaves on the bottom. They are rarely seen as they emerge from the river to fly as dusk falls and they only fly for a short period, maybe two to three hours, during the night. Swarms may continue all night but emergence ceases as the sun starts to rise. Dawn swarms continue for an hour or two after sunrise. The caenids are poor fliers and dispersal is also restricted. Five species are commonly found along the Murray River. *Irpacaenis deani* and an undescribed species *Tasmanocoenis* sp. B is found in the Headwater tract down to Albury; *Tasmanocoenis* sp. B, *Tasmanocoenis tillyardi, Tasmanocoenis tonnoiri* and *Tasmanocoenis arcuata* occur from Albury downstream to Echuca; and *Tasmanocoenis tillyardi* and *Tasmanocoenis arcuata* are common in the Riverine, Mallee and Lower Murray tracts. The two headwater species *I. deani* and *Tasmanocoenis* sp. B appear to be influenced by inter-basin transfers of water from the Snowy River catchment. *Irpacaenis deani* has higher abundances above the transfer point at Khancoban and *Tasmanocoenis* sp. B increases downstream of the transfer point (McInerney 2000). In years when transfer volumes are high *Tasmanocoenis* sp. B abundances increase and years when transfer volumes are low favours *Irpacaenis deani*.

Odonata (Damselflies and dragonflies)

The dragonflies and damselflies have aquatic larval stages and terrestrial adults. Sixteen species of damselflies and 28 species of dragonflies have been recorded from the Murray River and its floodplain. They represent less than 5% of the macroinvertebrate community in the main channel of the river (Bennison *et al.* 1989), but up to 10% in the wetlands. Many of the species are obligate stream-dwellers, restricted to the flowing part of the river channel. However, downstream from Echuca the river flow has been reduced by the construction of many locks which form large impoundments of still-waters which have allowed colonisation by standing water species.

In the montane section of the Headwater tract the damselflies (Zygoptera) are restricted to three species, *Austroargiolestes calcaris*, *A. icteromelas* and *Synlestes weyersii*. The fauna changes after Khancoban to a valley fauna, with *Nososticta solida* and *Rhadinosticta simplex* the dominant damselflies down the length of the river with *Pseudagrion aureofrons* from Lake Mulwala to South Australia. The floodplain wetlands contain standing water species *Xanthagrion erythroneurum, Austrolestes analis, A. leda, Ischnura heterosticta* and *I. aurora*.

The dominant species of dragonflies (Anisoptera) in the upper montane reaches of the Headwater tract are *Austroaeschna flavomaculata*, and *Synthemis eustalacta* the larvae of which survive the winter

snow conditions. Below the snow line the dragonfly fauna is characterised by the gomphids *Austrogomphus guerini*, *Hemigomphus gouldii*, the aeshnids, *Austroaeshna atrata*, *A. inermis*, *A. pulchra* and the synthemistid, *Eusynthemis brevistyla*. The fauna changes after Khancoban to a valley fauna of *Austroaeschna unicornis*, *Austrogomphus ochraceus*, *Apocordulia macrops*, *Cordulephya pygmaea* and *Eusynthemis virgula*. *Austroaeschna unicornis* ranges from the Khancoban valley reach through to South Australia, whereas the other species are only common to above Lake Mulwala, except for *A. macrops* which has been recently collected from the Barmah Forest, near Mathoura (Hawking unpubl. data). The gomphid *A. ochraceus* is replaced by its congener *A. australiae* from Lake Mulwala to the lower reaches in South Australia. *Hemicordulia tau* is very abundant in the lakes and locks but it also found along the total length of the river. The opportunistic species, *Hemianax papuensis* (Fig. 10), *Orthetrum caledonicum*, *Diplacodes bipunctata* and *D. haematodes*, can be found in the slow flowing and backwater areas of the lower Murray now occurring in both the wetlands and main channel.

Plecoptera (Stoneflies)

Stoneflies are cold water adapted and the nymphs of most stoneflies occur throughout winter and spring, and are rarely found during summer. McInerney (2000) recorded reduced abundance of stoneflies in spring to summer as they emerged to terrestrial adults. Stoneflies are generally found in fast flowing cool water streams and rarely occur in wetlands on the floodplain.

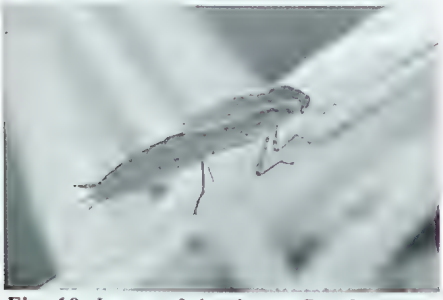

Fig. 10. Larva of the dragonfly *Hemianax papuensis*.

Therefore they are almost all restricted to the Headwater tract where their relative abundance is less than 5% of the macroinvertebrate community. Stoneflies do occur in the Riverine tract in areas of fast flows and usually a constricted river channel (e.g. the Barmah Choke). The Murray River fauna has representatives from four families, with the Gripoterygidae being dominant with at least 15 species in the genera *Dinotoperla*, *Riekoperla*, *Newmanoperla*, *Illiesoperla* and *Leptoperla*. McInerney (2000) recorded abundant *Dinotoperla serricauda* and *Riekoperla rugosa* downstream of the Khancoban pondage due to the reduced temperature of the water from the Snowy inter basin transfer. Downstream of Albury stoneflies are rare with *Dinotoperla serricauda* being recorded in the Mallee tract where the velocity of water is high. In the lower river tract only one species has been found. *Dinotoperla evansi* was recorded in the Murray River near Murray Bridge. This warm water species also lives in farm dams (Suter and Bishop 1990) and may well have colonised the lower Murray from this source.

The other families represented are the Austroperlidae, Notonemouridae and Eustheniidae. The Eustheniidae are predatory stoneflies and are represented by three genera, *Cosmioperla, Thaumatoperla* and *Eusthenia*. These large insects are only found high in the headwaters of the upland tributaries of the Murray River. Also only in the headwater tributaries are the Notonemouridae (*Austrocerca tasmanica*) and the Austroperlidae (*Austropentura victoriae*, and *Acruroperla atra*). *Acruroperla atra* is found associated with accumulations of dead leaves or leaf packs in pools in the upper catchment.

Megaloptera (Dobsonflies)

The Corydalidae are large (up to 50 mm) predatory aquatic insects with a short lived terrestrial adult. They are represented in the Murray River by a single species *Archichauliodes (Riekochauliodes) guttiferus* (Walker) which is restricted to the Headwater tract where the river is fast flowing and the substrate is dominated by rocks and cobbles overlying sand. *Archichauliodes* larvae can also be found under rocks in dry stream beds in upper catchment intermittent streams.

Fig. 11. A backswimmer (Notonectidae).

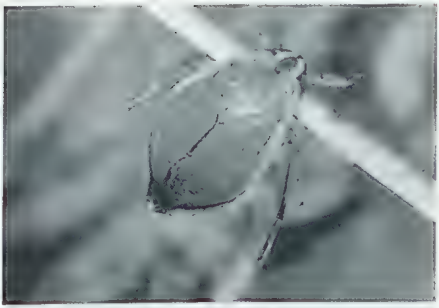

Fig. 12. The giant water bug *Diplonychus eques* (Belostomatidae).

Hemiptera (True bugs)

Aquatic bugs are characteristic of still waters and backwaters, and so are often associated with wetlands rather than rivers. In the Murray over 30 species are recorded from along the bank edge of the main river usually in areas where flows are slow but their relative abundance is less than 5%. The aquatic bugs are nearly all predators and consume gaseous oxygen from the air rather than dissolved oxygen from within the water. They lay their eggs in or on plants or attached to a firm substrate (Lansbury and Lake 2002) and the females of one genus of giant water bugs (Belostomatidae: *Diplonychus*) lay their eggs on the back of the males (Hawking and Smith 1997). The aquatic bugs occupy two distinct habitats, being either fully aquatic or surface dwellers.

The fully aquatic bugs are dominated by the water boatmen (Corixidae), with *Micronecta*, *Sigara*, and *Agraptocorixa* the most common genera, and the backswimmers (Notonectidae; Fig. 11) represented in the Murray River by *Anisops* and *Enithares*. *Micronecta annae* is common along the whole length of the river and in floodplain wetlands. *M. gracilis* and *M. robusta* are also common in the Riverine, Mallee and Lower Murray tracts. In the main channel of the Murray, *Sigara sublaevifrons* and *Agraptocorixa hirtifrons* appear restricted to the Headwater tract, but it is widespread in wetlands from Albury to South Australia (Suter *et al.* 1993). *Sigara truncatipala* is restricted to the Lower Murray tract whereas *Agraptocorixa eurynome* was throughout the river's length.

Four other families, Nepidae, Naucoridae and Belostomatidae (Fig. 12) and Pleidae are also fully aquatic and occur in the Murray, but usually are rare and mainly associated with floodplain wetlands. The Nepidae are represented by the water scorpion (*Laccotrephes tristis)* and the needle bug (*Ranatra dispar*). These are large species (up to 50 mm) with a long respiratory tube extending from their abdomen which enables them to hunt below the water surface and breath air through the tube which they extend beyond the surface tension of the water. The giant water bug *Diplonychus eques* (Belostomatidae) and the creeping water bug *Naucoris congrex* (Naucoridae) are also quite large (>15 mm long) and occur in macrophytes particularly in floodplain wetlands. As the name suggests the pygmy backswimmers (Pleidae) are quite small (<2.5 mm) which makes this group rarely seen, but they do occur in wetlands along the Murray.

The surface dwelling bugs include the water striders *Tenagogerris, Rheumatometra*, and *Limnogonus* (Gerridae), the small water striders *Microvelia* (Veliidae), the water treaders *Mesovelia* (Mesoveliidae) and the water measurers *Hydrometra* (Hydrometridae). These taxa occur in both the main channel and floodplain wetlands of the Murray River. *Tenagogerris euphrosyne* and *Rheumatometra philarete* occur in the Headwater tract and *Limnogonus* sp in the Riverine, Mallee and Lower river tracts. *Microvelia oceanica* occurs in the Riverine tract, *Microvelia peramoena* along the full length of the river including floodplain wetlands and *Mesovelia hungerfordi* is found in all tracts of the Murray both in the river and its wetlands.

Neuroptera (Lacewings)

There are two families of lacewings that occur in the Murray River, the Osmylidae and the Sisyridae. The osmylids (*Kempynus* sp.) are often found on large rocks and boulders in the splash zone in small upland streams, and have not been recorded downstream of Jingellic. The sisyrids or sponge flies (*Sisyra* sp.) occur in the Murray but are rarely found as they live in sponges on logs or rocks. Sponge-flies lay their eggs on vegetation overhanging a stream and the emergent larvae drop to the water and swim to a freshwater sponge. The larvae use their long straight jaws to probe the sponge tissue and feed on the contents (New 1991). They have been collected from logs in the Barmah-Millewa forest but may be more widespread, wherever sponges occur.

Coleoptera (Beetles)

Bennison *et al.* (1989) recorded the beetles as the second most species rich group of aquatic macroinvertebrates in the Murray River. Over 90 species were recorded with greatest richness in the Headwater and Riverine tracts. The beetles represented 15-20% of the composition of the macroinvertebrate community in the Headwater tract, less than 15% in the Riverine tract, less than 3% in the Mallee tract and less than 10% in the Lower Murray tract. Both the riffle beetles (Elmidae) and tiger beetles (Dytiscidae) dominated the Headwater tract but many species of the tiger beetles were also common in the Riverine, Mallee and Lower Murray tracts, particularly in the floodplain wetlands.

The riffle beetles can be found feeding on algae attached to logs and rocks in fast flowing streams in the upper catchment where they are both abundant and species rich. The headwater streams have at least 10 species within the genera *Kingolus, Simsonia, Notriolus* and *Austrolimnius*. Downstream of Albury the numbers of species and genera declines with only *Kingolus*, *Austrolimnius* and *Coxelmis* (total of five species) in the Riverine tract and only a single species of *Kingolus* and *Coxelmis* in the Mallee and Lower Murray tracts. In the lower gradient stretches of the Murray the elmids are found associated with logs and snags.

The predatory diving/tiger beetles (Fig. 13) are very active hunters that use gaseous oxygen to breathe and therefore must return often to the water surface to replenish their oxygen supply. They are usually associated with pool or pond habitats. Tiger beetles range from small (<5 mm), medium (5-15 mm) to large (15-34 mm). The small species in the Murray River include *Antiporus* with three species in the headwaters (*A. blakei, A. femoralis* and *A. gilberti*), but only a single species, *A. gilberti*, downstream of Albury. *Liodessus gemellus, L. amabalis* and *Sternopriscus multimaculatus* occur in the Lower Murray tract, whilst *Limbodessus compactus* and *Allodessus bistrigatus* are found along the full river's length. The medium sized tiger beetles include *Rhantus suturalis* found in the Headwater and Riverine tracts only, and the widespread *Eretes australis* and *Megaporus* sp that are found in wetlands in all tracts and occasionally in the main channel. The large predatory diving beetles *Cybister* sp has only been recorded from the Mallee tract.

Diptera (True flies)

The true flies are the most species rich of the aquatic insects in the Murray River with 158 different species recorded by (Bennison *et al.* 1989). It is likely that the number of species of dipterans is higher than this due to the improvements in the taxonomic literature since the study. The flies represented between 20 and 30% of the total species composition in the Headwater tract, but increased their dominance in the Riverine and Mallee tracts with 40 to 50% of the total species richness. In the lower Murray tract the impor-

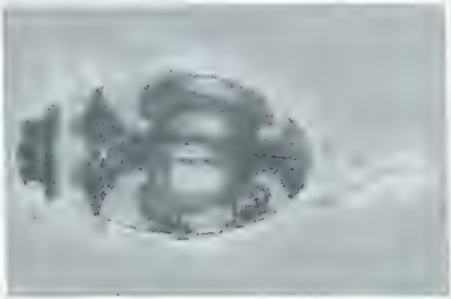

Fig. 13. The tiger beetle *Sternopriscus* (Dytiscidae).

tance of the dipterans declined to between 30 and 40%.

Adults of the biting midges (Ceratopogonidae), blackflies (Simuliidae) and mosquitoes (Culicidae) are the main nuisance insects associated with the river. The larvae of the ceratopogonids are found along the length of the Murray, but there are more species in the Riverine and Mallee tracts than in the Headwater or lower Murray tracts. These animals are more frequently found in the drying mud of wetlands and in the lower Murray in saline seepages along the cliffs near irrigation areas where they can cause significant nuisance value (e.g. Loxton; Suter unpublished data). The blackflies are usually associated with flowing water and firm stable substrates like rocks and logs. There are few species in the Murray all upstream of Swan Hill, with *Austrosimulium furiosum* in the Headwater tract, *Austrosimulium montanum, A. bancrofti, Simulium ornatipes* and *Simulium nicholsoni* in the Riverine tract. Mosquitoes are rare in the main channel of the Murray River, but they do breed on the floodplain particularly following floods when water becomes trapped in isolated pools and ponds.

The non-biting midges (Chironomidae) are the most diverse of the dipterans, and are found in all habitats along the length of the river. There are predatory midges (Tanypodinae), organic feeders (Chironominae, blood worms), filter feeders (Chironominae, Tanytarsini) and wood borers (Chironominae). The wood borer *Stenochironomus watsoni* is found in all tracts of the river associated with logs and submerged bark from riparian trees. Many of the filter feeders (*Kiefferulus martini, Rheotanytarsus* spp. and *Tanytarsus* spp.) also are associated with logs and snags where they build tubes from which they can catch organic material flowing past. *Rheotanytarsus* spp., which are only found in the Headwater tract, construct a silk net attached to its tube to trap its food. The Chironominae dominate the Riverine, Mallee and Lower Murray tracts.

An interesting observation was made by Pettigrove (1989) that the larvae of *Procladius paludicola* showed abnormalities of the mouthparts in the Mallee region of the Murray River. Similar abnormalities have been shown to be associated with exposure to chemicals such as heavy metals and pesticides (Madden *et al.* 1995; Madden *et al.* 1992; Warwick 1990). In the lower Murray tract *P. paludicola* is rare in the main channel of the river, but is the major predacious midge in saline evaporation basins and other wetlands on the floodplain (Suter *et al.* 1993; Suter *et al.* 1995). This species is also abundant in rice fields and with *Chironomus tepperi* can attain very high numbers and become a nuisance insect. *Chironomus tepperi* is an early coloniser of wetlands following floods and can attain very high numbers providing a primary food supply for native waterfowl (Maher and Carpenter 1984). However, in rice fields these large numbers can cause damage to the rice crop (Stevens 1995) thereby escalating these beneficial insects to an economic nuisance. The rapid colonisation and population growth of *C. tepperi* in floodplain wetlands and rice fields appears associated with the high levels of organic material present in the sediment (Suter *et al.* 1995).

Trichoptera (Caddisflies/Casemoths)

The caddisflies have a terrestrial stage that resembles a moth, but the larvae are aquatic and construct a diverse array of cases in which they live. In the main channel of the Murray the caddisflies represent approximately 15% of the aquatic community in the Headwater tract and between 5-15% in the Riverine, Mallee and Lower Murray tracts (Bennison *et al.* 1989). Although they are found in a wide range of habitats the greatest number of species occur in cool flowing streams and as such have a very distinct upper catchment distribution in the aquatic macroinvertebrate community of the Murray River. At least 12 families (Atriplectididae, Calamoceratidae, Calocidae/Helicophidae, Conoesucidae, Ecnomidae, Hydrobiosidae, Hydropsychidae, Hydroptilidae, Leptoceridae, Limnephilidae, Odontoceridae, Philorheithridae) with >30 species of caddisflies are recorded from the Headwater tract whereas the Riverine, Mallee and Lower Murray tracts have only 3 families present (Ecnomidae, Hydroptilidae and Leptoceridae) with fewer than 15 species.

The caddisflies are sensitive to environmental change, particularly in the high

quality waters of the upper catchment. They have a diverse range of habitat use and diet and so alteration to water quality, hydrology or addition of pollutants affects their community structure. McInerney (2000) found that there was a reduction of the community structure of the caddisflies as a response to the inter-basin transfer of water from the Snowy Scheme. The predacious caddisflies *Taschorema evansi* and *Ecnomina* sp. show a reduction in abundance downstream of the inter-basin water transfer while the leptocerid caddisflies *Triplectides ciuskus* and *Triaenodes* sp. became more abundant downstream of the inflows.

The diet of larval caddisflies can be divided into three main types based on method of collection of food (Neboiss 1991). There are the net spinners, (Hydropsychidae) that construct silken retreats with a silk net at the entrance used to capture organic particles carried past in the current. The Hydropsychidae (Fig. 14) are almost restricted to the Headwater tract where three species of *Cheumatopsyche* and one species of *Diplectrona* occur. However, *Cheumatopsyche* also occurs downstream of Hume and Yarrawonga weirs where there is fast flowing water. The case makers (Calamoceratidae, Calocidae, Helicophidae, Conoesucidae, Hydroptilidae, Leptoceridae, Limnophilidae, Odontoceridae and Philorheithridae) shred and chew on leaves, or graze on algae. The Leptoceridae is the most species rich family in the Murray. In the headwaters at least 12 species are found mainly in the genera *Notalina* (5 spp.) *Triplectides* (4 spp.), *Oecetis* (2 spp.) and *Triaenodes* (1 sp.). *Triplectides australis* and *Triplectides australicus* occur along the length of the Murray with *T. australis* mainly in the main channel and *T. australicus* in the floodplain wetlands. *Lectrides varians*, an endemic species to South Australia, occurs in the lower Murray near Murray Bridge.

The third group include the free living Ecnomidae and Hydrobiosidae. Species in these families are predators. The ecnomids occur throughout the river and its floodplain, but at the species level there are distinct changes from headwaters to Lake Alexandrina. In the headwaters three

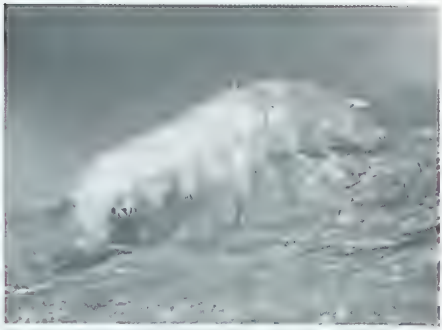

Fig. 14. Larva of the Hydropsychidae (Trichoptera).

species occur with *Ecnomus pansus, E. continentalis*, and *Ecnomina* F sp. AV9 (Cartwright 1997) common in the rivers and streams, but downstream of Albury *E. pansus* is only found in the Riverine and Mallee tracts. In the Albury area *E. pansus* occurs in the main channel of the river and *E. turgidus* and *E. cygnitus* are found in wetlands on the floodplain. In South Australia *E. pansus* and *E. russellius* are both in the main channel and *E. turgidus* occurs with *E. pansus* in the wetlands.

Lepidoptera (Aquatic moths)

Moths of the family Pyralidae, subfamily Nymphulinae (Fig. 15), are the only lepidopteran group to have aquatic larvae or aquatic caterpillars (Hawking 2001). The taxonomy of this group is still in its infancy although recent work has enabled different species to be recognised (Hawking 2001). Five species of pyralid are found along the Murray River. One species inhabits rocks in the fast flow regions of the Headwater tract. The larvae construct silk retreats on rocks and feed on the attached algae on the rock surface. In contrast the other four species are found on macrophytes. Three species occur in the ribbonweed beds (*Vallisnera*) in the fast flow of the upper Murray from Khancoban to Yarrawonga. They construct a case of *Vallisnera* strips attached to the plant leaf blades. One species is restricted to the pondweed *Potamogeton* in the slow flowing areas. The larvae construct a case by cutting a section of leaf and folding it back onto the leaf. This species is common in the *Potamogeton* beds of lower Murray River from Echuca to Woods Point.

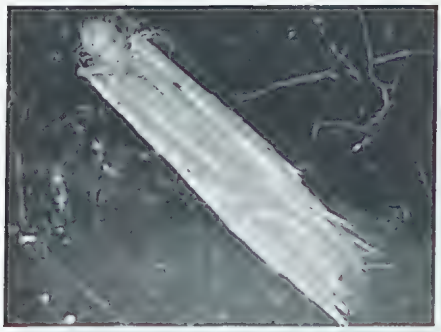

Fig. 15. Pyralid larva in its case (Nymphulinae).

Conclusion

This paper has attempted to give an overview of the aquatic macroinvertebrate fauna of the Murray River without attempting to give an assessment of the condition of the river. Norris *et al.* (2001) recently concluded that the macroinvertebrate communities along the Murray River from Dartmouth Dam to Lake Alexandrina were in poor condition. They also highlighted the absence of pristine or minimally modified sites in lowland rivers in the Murray Darling Basin and recommended caution in the interpretation of the results. The current distribution of the macroinvertebrates has certainly been modified by the influence of regulation, particularly in the Lower Murray tract where the river now is a series of narrow lakes and some species have benefited at the expense of others (e.g. the yabby replacing the Murray crayfish), and introduced species have successfully invaded the river (e.g. *Physa acuta*). However, it is not possible to determine the extent of modification of the invertebrate fauna because there are only limited data prior to construction of the locks and weirs. In addition, the other lowland rivers in the Murray Darling Basin with which the Murray communities could be compared are also affected by regulation. This lack of a reference condition limits the ability to assess the condition of the Murray but we are now in the position to monitor the effects of management decisions (e.g. environmental flows) on the aquatic macroinvertebrate communities of the Murray River.

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The Swamp Yabby (*Cherax* sp.) of the Murray River Catchment

Geoffrey N Edney[1], Dale G McNeil[2] and Susan H Lawler[2]

Abstract
The Swamp Yabby has been recently collected from Barmah State Forest, the Ovens River, Victoria and Deniliquin, NSW. Here we present the species in general terms and provide figures for identification. The Swamp Yabby differs from other *Cherax* species both in morphology and ecology. This animal resides primarily in burrows rather than the river. Burrowing *Cherax* were previously unknown in Victoria. (*The Victorian Naturalist* **119** (4), 2002, 200-204)

Introduction

The Swamp Yabby has been known to locals, fishermen, rangers and scientists for some time but remains undescribed, despite specific promotional efforts by the Victorian Department of Natural Resources and Environment who even released a range of material identifying the Swamp Yabby as a conservation priority. The species is called *Cherax* sp. C in the preliminary key by Horwitz (1995). A full description cannot be achieved however, primarily due to the lack of specimens collected, and importantly, the absence of a female specimen. This prevents any taxonomic description, leaving the species without conservation status.

We have collected Swamp Yabbies (*Cherax* sp.) from three locations, the Ovens River floodplain in Victoria and the Murray and Edward/Gulpa floodplains in New South Wales. Specimens were collected from the Ovens near Wangaratta and the Edward/Gulpa near Deniliquin through excavation of burrows. Depending on the water table, crayfish were located in burrows up to one metre in depth, whilst some large burrows were excavated to a depth of over a metre without locating a specimen. During a very minor flood on the Murray floodplain at Barmah, Swamp Yabbies were collected using submerged, baited hoop nets.

Other investigators have reported collecting Swamp Yabbies from two more

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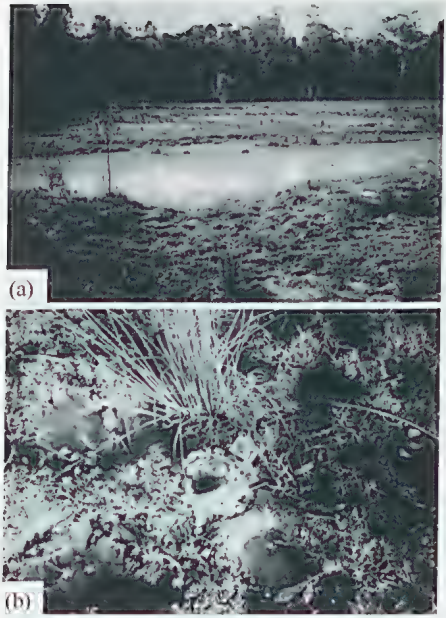


Fig. 1. The collecting site in the Barmah State Forest. a) The small stream in which the *Cherax* sp. were captured. b) The burrow entrance of *Cherax* sp. Note the cattle hoofprints trampling the burrow entrance. Matchbox indicates size.

Fig. 2. The collecting site near the Ovens River. At this site *Cherax* sp. was collected in a Red Gum floodplain forest.

Victorian tributaries of the Murray; at Lake Nagambie, on the Goulburn River, south of Shepparton (Royal 2002) and Lake Nillahcootie, near Mansfield on the Broken River (Brian Woodbridge pers. comm.). This suggests that their range covers not only the floodplains of the Murray and its associated anabranches, but also the three most significant Murray tributaries of north-eastern Victoria.

Description of collections

Eleven specimens were examined (Table 1). Three were caught in open water in the Barmah State Forest, Victoria, and seven were dug from burrows near the Ovens River, Victoria, and the Murray River at Deniliquin, New South Wales. An additional juvenile specimen was kindly provided by Brian Woodbridge of the Murray River Aquarium in Echuca, Victoria, who successfully bred them in captivity.

The Barmah State Forest site was a low dry floodplain with a small, slow-flowing creek at its centre. Cattle were grazing in the area. These crayfish were found in water that was 10-20 cm deep and they were caught late at night. Nearby burrows were clearly visible (Fig. 1).

The burrows at the Ovens River were on elevated land between billabongs. This land would be underwater only during flood events and is usually about two to three metres above the water level. It is currently used for cattle grazing. The chimneys (entrances to Swamp Yabby burrows) at the Ovens River were 30-40 m from the closest billabong (Fig. 2).

Identification

The Swamp Yabby has a unique morphology and is easy to recognise. Anecdotal evidence suggests a community awareness of a 'large black yabby with huge claws'. An unknown ranger at Barmah State Forest called the animals 'Moonclaws', in response to its large, crescent shaped claws.

The species is easily recognised by its claws, which are very broad and have a paddle-like protrusion (Fig. 3). It is also often larger than *Cherax destructor* collected from the same site. Three Swamp Yabbies from Barmah showed occipital carapace lengths (OCL) of 70, 70 and 75 mm, while we caught over fifty *C. destructor*, the largest of which was 60 mm OCL. We expect that larger specimens of both species occur.

Sympatric crayfish species

The Swamp Yabby does not occur in isolation. It coexists with the Common Yabby *C. destructor* throughout its entire range, and with the Murray River Crayfish *Euastacus armatus* throughout most of its

Table 1. Swamp Yabbies examined by the authors. Sizes are given in mm OCL (occipital carapace length: from the eye to where the carapace joins the tail). † at 2 years of age

Site	Sex	Number collected	Size range	Collected by (*raised by)
Murray River at Barmah State Forest, Victoria	male	3	70-75	GNE
Ovens River, Wangaratta, Victoria	male	2	50-60	GNE & DGM
Edward/Gulpa Junction, Deniliquin, NSW	male	5	50-70	DGM
Murray River Aquarium, Echuca, Victoria	male	1	34†	BW*

range. It is sympatric with the burrowing species *Engaeus lyelli* and *Engaeus cymus* (Horwitz 1990), and with the genus *Geocharax* (Tyler *et al.* 1983).

Behaviour, inter- and intra-specific competition

From our observations, it seems that the Swamp Yabby is more aggressive than *C. destructor* and is likely to outcompete it in the wild. When divided by a barrier within the same aquarium, the Swamp Yabbies made extreme exertions to breech the barrier. When no barrier was provided, *C. destructor* were immediately attacked and swiftly killed unless they left the water via an emergent stick or rock.

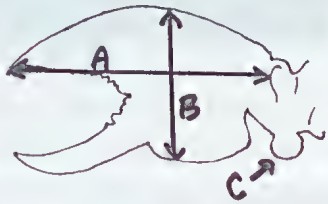
Swamp yabbies also exhibit strong intraspecific aggression. Four Swamp Yabbies were placed in aquaria (160 × 40 cm), and isolated in four small burrows separated by dry earth barriers. After the first night the smallest individual had been cut in half and only one individual survived the first week. This individual subsequently survived in the aquarium for over a year. Swamp yabbies appear to have quite a soft carapace compared with *C. destructor*. Although this may be an adaptation to burrowing, it is surely a disadvantage during intraspecific competition. There was no evidence of cannibalism after death from these competitive bouts.

The degree of habitat partitioning between Swamp Yabbies and *C. destructor* in the wild is uncertain. *Cherax destructor* were never found in Swamp Yabby burrows although they did exist in shallow simple burrows in the same dry billabong as the Swamp Yabby. Only single specimens of Swamp Yabbies were found within each burrow, suggesting a non-colonial burrowing system.

Crayfish burrows

Australian freshwater crayfish burrows have been classified by Horwitz and Richardson (1986). Three types are recognised: burrows opening below the water surface in a permanent water body, burrows connected to the water table but not to a stream or lake and burrows independent of the water table. Ellen Clark anticipated this scheme with her terms aquatic, semi-aquatic and terrestrial (Clark 1936).

(a)



(b)

Fig. 3. a) The Swamp Yabby (*Cherax* sp.). b) To identify a Swamp Yabby, the width of the claw (B) is more than 50% of the length (A), and a paddle (C) is present on the claw.

The genus *Cherax* is known to construct burrows which are always connected either to a permanent water body or to the water table (Horwitz and Richardson 1986). There are three burrowing *Cherax* known from Queensland: *C. punctatus*, *C. robustus* and *C. cartalacoolah* (Short 1993). All of them are smaller than the Swamp Yabby and burrow in sandy substrates. The burrows of *Cherax plebejus*, from southwest

Western Australia, descend vertically to a small chamber where one often finds a male and a female (Horwitz and Knott 1983).

Burrowing by the Swamp Yabby

The Swamp Yabby constructs a burrow that is always connected to a permanent watercourse or to the water table (Type 2 as described by Horwitz and Richardson 1986). Some entrances were freshly sealed with mud indicating the presence of water within the burrow system. The Swamp Yabby appears to remain in its burrow for much of the time. The burrow covers more than one cubic metre and could be much larger underground. A surface chimney leads to a tunnel which descends for a short distance and then will branch or join a chamber.

The burrow has several chambers which are about the size of a football. Some are used for storing water. There are often multiple tunnels connecting chambers and several surface holes. Burrows of the Swamp Yabby can be distinguished from those of *C. destructor* and *Engaeus* by the sheer size of the entrance hole: usually 5-8 cm in diameter vs 1-2 cm for *Engaeus* and generally <4 cm for *C. destructor*.

To date we have only collected males, and other workers have confirmed an extremely skewed sex ratio (Tarmo Raadik and Brian Woodbridge pers. comm.). The reasons for this are unknown. It is possible that there is some sexual habitat segregation, however current collecting techniques may somehow be biased towards finding males. Females may live in extremely deep burrows and remain non-emergent during small floods.

Associated fauna

Burrowing crayfish are known to support a large and often unique fauna termed the 'pholeteros'. Their burrows are refuges for other animals during drought. We have observed an *Engaeus lyelli* and a large number of the frogs *Limnodynastes tasmaniensis* in burrows during our excavations. The burrows of other crayfish often support faunal assemblages (Horwitz and Knott 1981; Suter and Richardson 1977). In addition, the crayfish themselves support a diverse ectofauna, which are animals that live on their shells, tails and gills.

Fig. 4. A Swamp Yabby surrounded by ectosymbiotic worms *Temnosewellia minor*. Photo by Karli Hawking.

Temnocephalans (Fig. 4) are ecto-symbiotic worms that lay eggs under the tailfins and live on the carapace of crayfish (Cannon 1991; Cannon and Sewell 1994, 1995; Sewell and Cannon 1995, 1998). They filter feed and are attached by a large caudal sucker. Large numbers of temnocephalans were observed on all Swamp Yabbies collected. Some of these were sent to Lester Cannon of the Queensland Museum, who identified them as *Temnosewellia minor*, a species known to be common on *Cherax* in the Murray River catchment. Temnocephalans are turbellarian flatworms known to be symbiotic on freshwater crayfish throughout Australia (Cannon 1991). The worms are nearly as variable as their hosts, and may be species specific in many cases (Cannon and Sewell 1994).

Impacts and conservation

All of our sites were grazed by cattle. The soil showed extensive disturbance from trampling and grazing. There is anecdotal evidence that cattle impact heavily on Swamp Yabbies and many Swamp Yabby burrows were found within hoofprints and with flattened chimneys. Crayfish chimneys were scarce in the open and more common around fallen logs and roots. These habitats provide protection from soil disturbance such as during floods or trampling, and may provide a food source, attracting invertebrates during decomposition.

In 1936 farmers were complaining about losing cattle and horses in 'crab-hole country' near Benalla, Victoria (Clark 1936), and anecdotal evidence suggests that these complexes were always ploughed in for safety. Although the species responsible

has never been identified, similar collapses have been reported due to extensive burrowing by *Engaeus* (Clark 1936). The Benalla area, however, is now known to be central to the Swamp Yabby distribution and it is possible that these 'crab' hole areas may have been the result of large aggregations of Swamp Yabby burrows.

Furthermore, the Murray, Edward/Gulpa, Broken, and Goulbourn Rivers are all highly regulated. High winter and spring flows, that would have traditionally flooded Swamp Yabby habitats no longer occur. The effect of these impacts on Swamp Yabbies and their habitat warrants further investigation. The Ovens River, which remains mostly unregulated, provides a good opportunity to observe Swamp Yabby habitat in a more natural flooding regime. The destruction of such large burrow complexes, and the deterioration of natural flow conditions suggest that past land practices may have had a large impact on Swamp Yabby habitat. 'Crab-hole country' is virtually gone now from the Benalla area. It is now difficult to ascertain how these land practices may have impacted upon Swamp Yabby populations in the past and how these may have affected its distribution and ecology.

Disturbance has been shown to affect crayfish populations elsewhere in Australia (Growns 1995), and it is possible that many former populations have disappeared due to human disturbance. It should also be noted that the large complex of chimneys which first drew our attention to the presence of the Swamp Yabby on the Ovens River was graded to make a drainage channel during roadmaking activities in 1998. Although some burrows still persist there, it is clear that current land use also has an impact upon the Swamp Yabby and its habitat.

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Murray River Microfauna

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Abstract
The microfauna of the Murray and tributaries is a speciose, albeit neglected, component of the riverine biota. The community derives from diverse in-stream ,and, seasonally, off-stream sources. There are regional differences in species composition – tributaries may contribute different taxa to the mainstream river. A mixed assemblage of protists, rotifers and microcrustaceans persists into the lower Murray, with longitudinal changes in species composition during long travel times to the river mouth. Effects of river regulation, land use and salinisation on microfaunal biodiversity are summarised. (*The Victorian Naturalist* **119** (4), 2002, 205-211)

Introduction

In marked contrast to the recent surge of research activity on macroinvertebrate taxonomy and ecology in the Murray-Darling Basin, spurred by river health initiatives and pressure for biodiversity information, the microfauna of Murray-Darling waters remains largely neglected. Microfauna regulate bacterial and algal abundance, and occupy important links in food chains for higher order consumers such as macroinvertebrates, fish and birds. In most Australian freshwater ecosystems, but particularly in the Murray-Darling system, these connections have been under-estimated or ignored (Green and Shiel 1992).

What little information exists on the microfaunal component of the Murray River and tributaries derives largely from a few local studies. Species composition and successional events in littoral microcrustacea from a year-long study of a Goulburn River billabong were documented by Shiel (1976). The zooplankton of Lake Hume was reported by Walker and Hillman (1977), that of several other impoundments by Powling (1980). A basin-wide survey, published in part by Shiel *et al.* (1982), demonstrated the disparate nature of the microbiota of the west-flowing Murray River and the south-flowing Darling River. The former contained a cool-temperate microcrustacean-dominated lacustrine (limnoplankton) assemblage, attributed to the serially-impounded nature of the Murray River, the latter a true riverine (potamoplankton) community dominated by rotifers, many of which are warm-stenotherms or tropical in affinity.

The role of turbidity in structuring zooplankton communities in Lake Alexandrina, at the Murray mouth in South Australia, was examined by Geddes (1984). Boon *et al.* (1990) reviewed information on upper Murray billabong ecology, including microbiota, for the Murray-Darling Basin Commission volume '*The Murray*'; information on riverine zooplankton was reviewed for the same volume (Shiel 1990). Other relevant and more recent studies include: invertebrate emergence from flooded sediments (Boulton and Lloyd 1992), rapid responses to flood events by billabong rotifer assemblages (Tan and Shiel 1993), Lakes Hume and Dartmouth zooplankton in the context of biomanipulation (Matveev and Matveev 1997), heterogeneity of habitat and microfaunal biodiversity across ephemeral wetlands (Shiel *et al.* 1998), fish predation on zooplankton (Nielsen *et al.* 2000a, b) and the role of propagules in sediments (Langley *et al.* 2001; Nielsen *et al.* 2002; Shiel *et al.* 2001; Skinner *et al.* 2001).

Composition of Murray River microfauna

Three broad groups of microinvertebrates comprise the bulk of pelagic and littoral communities in Murray-Darling waters, *viz.* protists (Protista), rotifers (Rotifera) and a suite of microcrustacea dominated by copepods (Crustacea: Copepoda), cladocerans (Crustacea: Branchiopoda: Anomopoda/Ctenopoda) and (occasionally) ostracods (Crustacea: Ostracoda). Other groups occurring in microfaunal samples include larvae or small adults of various insects, particularly Diptera and Hemiptera, and water mites (most often Hydracarina or Oribatida). These latter groups may be abundant seasonally and be important in structuring microfaunal

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assemblages through food web interactions, however, for the purposes of this review, only the major groups are treated further.

***Protista*:** Protists (or protozoa, unicellular heterotrophs) include flagellates, ciliates and amoebae, both naked and testate. They are commonly the numerically dominant animals in any sample taken from Murray River standing (lentic) or slow-flowing (lotic) waters. Protists are under-represented in rapidly-flowing lotic waters; they are relatively fragile, and do not survive.

Protists, remarkably, have received only cursory mention in Murray River ecological studies, if they are mentioned at all. The lack of study of Australian ciliates, for example, was regarded as 'regrettable and somewhat astonishing' when an endemic Murray River loricate ciliate was described (Foissner and O'Donoghue 1990). The age of the continent and the potential for isolation to drive speciation events were seen as significant in predicting a diverse indigenous protist community.

A suggestion that Australian protist assemblages may differ from those of the northern hemisphere was made by Laybourn-Parry *et al.* (1997), who collected *Stentor*, a mixotrophic (photosynthetic) ciliate, from two Murray-Darling reservoirs (Tuggeranong, ACT and Hume, NSW). *Stentor* blooms colouring the water black have long been reported from Murray River waters (e.g. as 'cf. *Climacostomum*' in Walker and Hillman 1977), where densities >50,000 l^{-1} have been recorded (cited in Laybourn-Parry *et al.* 1997). *Stentor* is uncommon in northern hemisphere waters, where it is subjected to heavy predation by, *inter alia*, cyclopoid copepods. The latter are rare in Murray River reservoirs, which tend to be dominated by herbivorous calanoid copepods (see below), hence predation pressure on *Stentor* appears to be low. *Stentor* also reaches bloom populations seasonally in some Murray River billabongs (cf. Fig. 1, Shiel 1990).

Further evidence for distinctive protist assemblages comes from a recent study of testate amoebae in the upper Murray catchment (Meisterfeld and Tan 1998). They reported a rich testate community in the environs of Lake Catani, Mt Buffalo, with 89 taxa, 34 of them new to Australia, recorded from eight *Sphagnum*/sediment samples. Six of the testates were noted as 'strictly Gondwanan' in distribution. Several others were undescribed and possibly Australian endemics. New records of naked amoebae (Heliozoa) also were reported from ponds in the Mt Buffalo region (Mikrjukov and Croome 1998). Given that almost half of the amoebae reported in these two small surveys were new to the Australian fauna, it would seem that a diverse and unrecorded protist fauna awaits discovery!

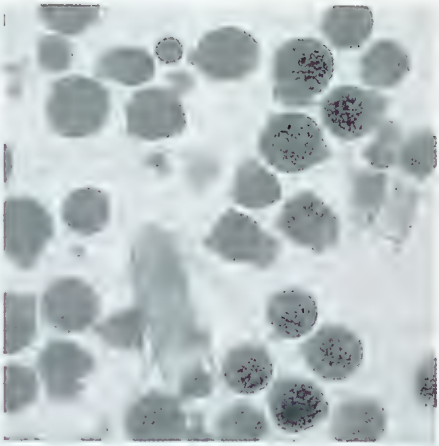

Fig. 1. *Stentor* cf. *amethystinus* in Ryan's #1 billabong, Murray River floodplain near Bonegilla, Victoria. Photo by Russell Shiel.

The only group of protists which has been studied intensively in Murray River waters is the freshwater Acanthamoeba *Naegleria*, particularly in the lower Murray in South Australia, from which Adelaide and other regional centres draw drinking water. As the causative organism of amoebic meningitis, *Naegleria*, and other pathogenic protists such as *Giardia*, are continuously monitored by the Australian Water Quality Centre at Bolivar, South Australia.

Given the paucity of studies on protists in Murray-Darling waters, little can be said of their potential for bioindication or their biodiversity in any of the Basin's waters, which is remarkable given the level of research effort applied to protists elsewhere (see, for example, Foissner and Berger 1996).

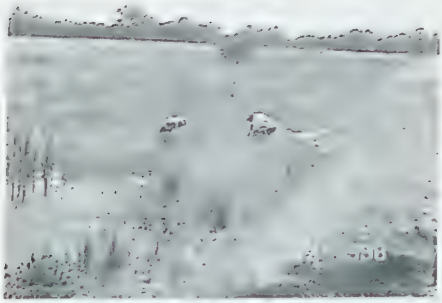

Fig. 2. Collecting sediment cores from Ryan's #3, Bonegilla. Photo by Russell Shiel.

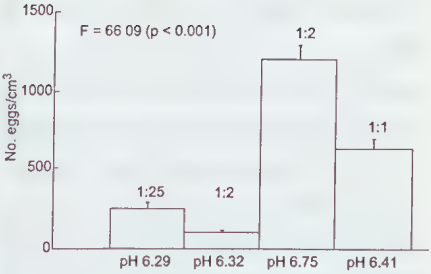

Fig. 3. Resting egg counts in sediments from three flood frequencies: annual, biennial and every c. 25 years (from Shiel *et al.* 2001).

Rotifera: Rotifers, the smallest metazoans, with most <200 µm in size, are commonly the most abundant microfauna after protists. More than 600 of the 720 rotifer species now known from Australia have been recorded from Murray-Darling waters (Shiel unpubl. data). The greatest rotifer biodiversity is found in ephemeral waters, where >100 co-occurring species have been collected in single net tows (Shiel *et al.* 1998). Billabongs also support rich rotifer assemblages by virtue of the vegetated, partitioned habitat; >350 microfaunal species, including >200 rotifer spp., have been recorded from an ephemeral pool over more than 20 years of sampling (Langley *et al.* 2001; Shiel *et al.* 2001). More commonly, a collection will contain 5-50 rotifer spp., depending on structural complexity of the habitat – densely vegetated and therefore partitioned billabongs have more species than does the open water of reservoirs and rivers. Floating and submerged vegetation provides some protection from visual predators. Rotifers occupy all feeding niches in such partitioned habitats – detritivores, bacteriovores, herbivores, carnivores and parasites. Suites of each of these feeding groups may co-occur. For example, several co-occurring species of *Brachionus*, *Filinia, Keratella* or *Trichocerca* may overcome the problem of competition for resources by taking different size food items. Experimental evidence suggests that even bacteria may be partitioned in a similar manner, by size, morphology or chemistry (Boon and Shiel 1990). Rotifers are able to persist in ephemeral habitats by production of resistant resting eggs, which remain in dry sediment until rewetting and appropriate cues to hatching. All resting eggs do not respond to the same cues, hence there is a succession of hatching events, with concomitant compositional changes the longer a previously dry habitat is flooded (Tan and Shiel 1993). Fig. 2 shows collection of dry sediment from the previously-wetted margin of Ryan's #3, a shallow ephemeral pool on the floodplain of the Murray River adjacent to Ryan's #1, a permanent billabong. Resting stages counted from 1 mm slices of 1 cm diameter cores taken from these sites showed significant differences in density (Fig. 3), up to 1200 cm^{-3}, with highest densities at the margin of Ryan's #3, the biennially flooded (ephemeral) site (Shiel *et al.* 2001).

Microcrustacea: Of the three main groups of microcrustaceans abundant in Murray River waters, copepods tend to predominate, with cladocerans either perennial in low numbers or markedly seasonal, when they may reach high densities. Ostracods, except in salinized waters, tend to be rare incursions from the littoral, their preferred habitat. Most abundant copepods in reservoirs and billabongs, and also often in weir pools and downstream reaches of the Murray and tributaries, are calanoids of the southern hemisphere family Centropagidae, commonly *Boeckella* and *Calamoecia* species, with *Hemiboeckella* species in ephemeral waters, and (rarely) the usually-coastal *Gladioferens* in downstream sites such as Lake Cullulleraine. Two species of the northern affinity Diaptomidae occur across northern

Australia, and may extend into the north of the Murray-Darling Basin (cf. Bayly 1966).

Of about 50 centropagid species known from Australia, the most common in Murray River waters, and across southern Australia generally, is *Boeckella triarticulata*, which occurs across a wide range of habitat types (Bayly 1992). In fish-free ephemeral habitats the large (4 mm) *B. major* may be a seasonal predator on other plankters (Green *et al.* 1999), with *B. pseudochelae* and *Hemiboeckella searli* also common in ephemeral waters. Billabong species include *B. fluvialis*, *B. minuta* and *B. symmetrica*, which may co-occur with one or more *Calamoecia* species, commonly *C. ampulla* or *C. lucasi*. Two or three co-occurring calanoids in a habitat is usual, four or five less so, and six is rare. Notably, salinized waters of mid-Murray regions around Kerang/Swan Hill have halophile calanoids, *Calamoecia salina* or *C. clitellata*, suggesting a much longer evolutionary history of salinization than that induced by human activities in the region in the last 200 years.

Cyclopoid copepods are less well known in Murray River waters. They are not common or abundant in the open water of reservoirs or rivers, but can be seasonally speciose and abundant in billabongs and ephemeral waters. They fill both herbivorous and carnivorous niches, prey including rotifers, other copepods, cladocerans and occasionally, small macroinvertebrates, e.g. mussel glochidia (juveniles). Most species are from the Family Cyclopidae, and about 100 spp. are known from the continent. Common genera are *Australocyclops* (a large predator), *Eucyclops, Mesocyclops,* and *Microcyclops*. The latter two genera are the most speciose based on present taxonomic information (e.g. Holynska 2000). As for calanoids, two or more species co-occurring at a site is common, often markedly different in size, thereby reducing competition.

A third group of copepods, the harpacticoids, are benthic in habit, rarely collected in open water, and poorly studied in Australasia. *Canthocamptus* species appear to be the most common in Murray River billabongs and ephemeral waters, associated with sediments and vegetation (cf. Hamond 1987).

Plankton collections are usually dominated by juveniles of the resident copepods, both nauplii and copepodite stages, and this presents a major taxonomic impediment to biodiversity studies. Not only does a researcher have to determine the species present, but also may need to discriminate the life stages. This is not an easy task when three or four species co-occur, and samples may include several copepodite and sub-adult instars, with one sex or the other required for species determination. Juveniles also tend to predominate in downstream river reaches; adults apparently are able to avoid outflows from weir pools or reservoirs.

Cladocerans ('water fleas') may make up a significant part of microfaunal community diversity in shallow vegetated habitats, but less so in open water of reservoirs and rivers, where their size renders them susceptible to predation by macroinvertebrates and fish. More than half of the c. 200 spp. of cladocerans now known from the continent occur in Murray-Darling waters. The family Chydoridae is the most diverse, and in excess of 100 species have been recorded from Australia, with more than half of them endemic (Shiel and Dickson 1995). More than 20 species of chydorids co-occurred in a Goulburn billabong (Shiel 1976) where they filled detritivore and herbivore niches. Many chydorids are adapted to scraping biofilms from surfaces, hence are littoral or epiphytic in habit. Only species of *Chydorus* tend to be collected in open water, and then associated with filamentous algal blooms where they collect food by scraping along filaments.

Only a few other cladoceran families have truly planktonic representatives in Murray River waters: *Bosmina* (Bosminidae) is common in reservoir and river plankton, as is *Diaphanosoma* (Sididae), and seasonally, *Moina* (Moinidae). *Daphnia* (Daphnidae), one of the larger cladocerans, tends to be seasonal in billabongs and ephemeral habitats, or perennial in low numbers in reservoirs, where it is probably subjected to heavy predation pressure. Smaller daphnids, such as *Ceriodaphnia*, are more often collected in

plankton tows. Other daphnid genera – *Simocephalus, Scapholeberis* – are billabong/shallow water dwellers. One daphnid genus, *Daphniopsis*, is a halophile, occurring in salinized waters throughout the Basin. Species of other families of cladocerans – Macrothricidae, Ilyocryptidae and larger sidids (e.g. *Latonopsis*) are usually found in shallow, vegetated habitats, particularly regularly inundated ephemeral pools.

Notably absent from Australia, possibly evolving after the breakup of Gondwana, are the northern hemisphere predatory cladoceran families Cercopagidae, Leptodoridae and Polyphemidae, which are important 'structurers' of plankton communities in northern hemisphere waters (Shiel and Dickson 1995; cf. Rivier 1998). Species of Podonidae are reported from coastal/marine waters around Australia but not from inland Australia (Smirnov and Timms 1983).

Ostracods, which include detritivores, herbivores and predators, occasionally are abundant in collections from billabongs and ephemeral pools. In some billabongs, five or six species of ostracods is not unusual – large species (e.g. *Australocypris, Mytilocypris*) may co-occur with smaller (e.g. *Cypretta, Limnocythere, Newnhamia*). Ostracods rarely appear in open water collections.

Sources of microfauna in the mainstem rivers

In Murray River waters there is no experimental evidence to demonstrate the contribution of headwater reservoir limnoplankton to downstream rivers, nor of contributions from floodplain lentic waters. From circumstantial evidence in the studies cited earlier, and from studies of river microfauna elsewhere (e.g. Baranyi *et al.* 2002), the persistent microfaunal community in downstream reaches reflects disparate contributions from upstream impoundments, floodplain waters which may at times have a connection to the river, regions of slow-flow such as backwaters or braided channels, waste stabilization ponds from riverside communities which may discharge into Murray tributaries, in fact any standing water which connects to the river at any time.

Geographical differences in source waters, regionalism in the microfauna and regional rainfall events will influence what particular assemblage is being inoculated into tributaries. Downstream weirs and locks on the Murray River provide low- or no-flow conditions and a longer retention time, which permits reconstitution of a microcrustacean assemblage. This is referred to in European studies as 'age' of the water, with rotifers dominating in waters of low 'age' (e.g. short retention-time storages such as Lake Mulwala) and microcrustacean assemblages appearing in waters of greater 'age' (e.g. long retention-time storages such as Lakes Dartmouth and Hume) (cf. Baranyi *et al.* 2002).

What this phenomenon reflects is the life cycle of the respective microfauna. At ambient temperatures in Murray River tributaries, rotifers are reproducing in days, microcrustacea in weeks. Rotifers are able to get through their life cycles in the short retention-time storages, microcrustacea are not. The latter require stable conditions for a longer period to reach adult reproductive stages and are unable to complete life cycles in turbulent or rapid through-flow storages. This life cycle disparity is the basis for the differences noted earlier (Shiel *et al.* 1982) between Murray and Darling microfauna. The microfauna of the Murray traverse a series of lentic or at least slow-flowing weir pools; those of the Darling below the headwater rivers a lotic system, at least until Menindee Lakes. Unlike the Murray system, which has an extensive network of lentic waters – a heterogeneous array of billabongs (Hillman 1986), intermittently flooded Barmah-Millewa Forest waters, the Macquarie Marshes, irrigation returns from tributary systems – the Darling is deeply incised (up to 10 m) into its floodplain, and lacks these sources of lentic microfauna. It remains a lotic, largely unimpeded system, albeit one of low flow.

Notably, a rotifer-dominated river microfauna (*Brachionus, Keratella* and *Synchaeta* dominants among 22 rotifer species) was collected from the Murray River near Morgan early in 2002 (MC Geddes pers. comm.), over 20 years after a very similar autumn river plankton was reported from the same reaches of the

lower Murray (Shiel *et al.* 1982). Despite widely publicised alterations to the flow regime, abstractions, declining water quality, the spread of carp and other deleterious effects of human interference with Murray waters, the microfauna appears remarkably little changed. Twenty years may be insignificant in the time frame of the Basin's ecological evolution.

Biogeography/endemism

Microfaunal biogeography is subject to two interpretations – that of the 'cosmopolitanists', for whom everything is everywhere, and the 'regionalists', for whom it is not. Many of the microfauna species found throughout Murray River waters are the same species found in rivers and lakes everywhere; they are indeed cosmopolitan. But some are not. If they occurred worldwide, surely they would have been recorded in some 300 years of microfaunal research in the northern hemisphere.

As noted earlier, the protists remain enigmatic. A small block of rotifers are more restricted, Gondwanan or Australasian on present distribution information. About 13-15% of rotifers are Australian endemics, or possibly more correctly 'Australasian'; some *Brachionus* species previously thought to be indigenous have been reported from Thailand (Sanoamuang *et al.* 1995). Most of the apparently indigenous rotifers are known from only one or a few habitats, primarily billabongs or small ephemeral waters, and appear to be restricted to them. The implication that they are thus endangered by loss of habitat is clear, but loss of species remains undocumented for the continent.

Cladocerans presently stand at c. 48% endemism, but this figure is likely to increase when taxa carrying 'northern hemisphere' names are examined more closely using modern methods (Shiel and Dickson 1995). The work of Bayly (cited in Bayly 1992) indicates that the level of endemism in the Australian calanoids approaches 90%. Cyclopoids are less intensively studied, but evidence to date (e.g. Holynska 2000) suggests that greater endemism will be revealed as the Australian 'cosmopolitan' species shed their 'European' names.

The future?

In the Murray-Darling Basin, as in salinizing wetlands in the southwest of Western Australia and in other degraded wetlands on continental Australia and Tasmania, species diversity is inversely related to salinity. The diverse microbiota of fresh waters is replaced by a halophile or halobiont assemblage tolerant of the new conditions. The new taxa may even be more abundant than the assemblage they replaced, but they are invariably less speciose. For example, the 100-species rotifer assemblage of upper Murray billabongs is replaced by one or two species of *Brachionus/Hexarthra* around Kerang, and the multispecies assemblage of *Boeckella/Calamoecia/Hemiboeckella* of upper Murray billabongs is replaced by *Calamoecia salina* or *C. clitellata* in the salinized downstream lakes. In the human time frame this decline in biodiversity is well documented for macrofauna . What is not documented is the loss of species at the microfaunal level due to loss of habitat. With greater than 70% of billabongs now gone from some floodplain reaches (e.g. Goulburn River downstream of Eildon), how many species previously found only in those billabongs are now lost?

Persistence of propagules in sediments, despite the loss of wetlands, may be used to counter the suggestion that microfaunal species are being lost at an increasingly rapid rate. But as mentioned earlier, resting stages may have specific cues for emergence, and habitat changes such as salinization may remove these cues. Decreased flooding frequency may exceed the life expectancy of a propagule – resting stages have a finite life, be it decades or perhaps centuries. Further, propagules evolved to resist desiccation, not trampling by cattle, or tractor and plough. The introduction of exotic planktivorous fish (e.g. *Gambusia*), either deliberately or accidentally, must also have had a profound impact on microfaunal populations.

In summary, it is evident that microfaunal heterogeneity persists in the more pristine (upper) Murray-Darling floodplain waters, and it is the floodplain which is the source of the biodiversity, not the reservoirs, which are relatively recent in an evolutionary time-frame, nor the rivers,

which transport microfauna and propagules. With loss of the more pristine wetlands due to agriculture, salinization, or other causes, the microfauna is lost, as ultimately, if not replenished, is the bank of cysts, resting eggs and ephippia in the sediments.

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Treasures from the Kingdom of Fungi

by Taylor F Lockwood

Publisher: *Taylor Lockwood, 2001. 128 pp, 250 colour photographs. RRP $55*
Available from Fungimap, Royal Botanic Gardens Melbourne, phone 03 9252 2374

The aptly titled *Treasures from the Kingdom of Fungi* is the long-awaited hardbound collection of Taylor Lockwood's amazing photographs. Taylor has been presenting these in slide shows around the world for the past 15 years. This 128 page book contains approximately 250 colour photographs of fungi, illustrating 157 taxa from 19 countries (including 25 Australian taxa). Text is limited to the preface, foreword and a brief introduction; most of the book consists of page after page of delightful photographs including many mushrooms but also a good selection of puffballs, stinkhorns, coral and bracket fungi.

The images are grouped together in chapters that divide the book aesthetically rather than scientifically. Chapters include 'The Span of the Rainbow' showing fungi of every colour of the rainbow, 'Foods of the Gods' illustrating some of the edible fungi, and a 'Lovers' Lane' of naturally-occurring, artistically-twinned examples. Each photograph is captioned merely with identification of the fungus (although some 20% are 'unidentified', not even to genus), and the general location where the photograph was taken (usually the country name only, but states are also listed for the USA examples). Taylor's enthusiasm for the topic is clearly evident with the layout and backgrounds on each carefully designed page showing great attention to detail.

Having spent many days in the field in search of perfect fungi to photograph, and having referred to many other books of field photography, I can personally attest to the difficulty of finding a good quality specimen and the skill required to capture it adequately for posterity. The broad range of superb field examples chosen as the subject matter in this book are evidence of Taylor's efforts 'on the ground', and his technical and creative talents as photographer are clearly demonstrated in the spectacular images that result.

One drawback of this book is the number of photographs labelled as 'unidentified'. Taylor does not collect specimens to allow identification at a later date, and some of the photographs are artistic rather than scientific, and so lack all the diagnostic features required for identification. However, scientific presentation is not the aim of this book. Taylor's goal was to inspire interest in and appreciation of fungi, which I feel he has well and truly accomplished with this collection. *Treasures from the Kingdom of Fungi* is not a field guide or scientific text (which should have few unidentified photographs and preferably include a scale), but a brilliant 'coffee table book' on fungi.

To produce a book without some typographical or grammatical errors would be an almost impossible task. There were a small number of general mistakes in this book as well as a few names spelt incorrectly; *Cyptotrama aspratum* (spelt as *asprata*), *Mycena leaiana* (incorrectly spelt *leiana*) and *Tremella fuciformis* (incorrectly spelt *fusiformis*), also in the index *Boletus* is spelt *Bolteus*, and *Cladonia* comes before *Cladina*. However, these certainly do not detract from the overall high standard of presentation.

The retail price of $55 for this book may seem a little high, but it is well worth considering for the bounty of beautiful, high quality images. Taylor's aim 'to inspire others into deeper appreciation of this special part of the natural world' has been admirably achieved by superbly illustrating the diversity of this often weird and wonderful kingdom. Although this is not a scientific text, I still feel it should be present on the book shelf of every mycologist and naturalist as an inspiration and delight if nothing else.

Simon H Lewis
Royal Botanic Gardens Melbourne
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Twelve Fungimap Target species are included (most showing diagnostic features): *Amanita phalloides* (var. *alba*) p. 45; *Ascocoryne sarcoides* p. 106; *Boletellus obscurecoccineus* p. 51; *Coprinus comatus* p. 118; *Craterellus cornucopioides* p. 121; *Cyptotrama aspratum* pp. 37, 55; *Lepista nuda* p. 118; *Mycena interrupta* pp. 31, 42; *Mycena leaiana* p. 86; *Podoserpula pusio* p. 28; *Pseudohydnum gelatinosum* pp. 20, 79; *Tremella fuciformis* p. 106.

The

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Research Report

Seasonal and Altitudinal Differences in the Abundance and Species Richness of Some Macroinvertebrates in Kosciuszko National Park, Australia, *by Michelle Stock and Catherine Marina Pickering* 216

Contributions

Observations on the Feeding Behaviour of Uchidanurinae (Collembola: Neanuridae) in Australia, *by Penelope Greenslade, Sean Moore and Roger Farrow* 221

Butterfly Management Uses Pollard Walk, *by Bryan T Haywood and Christopher J Wilson* 224

First Record of the Asian Freshwater Leech *Barbronia weberi* (Blanchard, 1897) (Euhirudinea: Erpobdellidae) in Australia, *by Fredric R Govedich, Bonnie A Bain and Ronald W Davies* 227

Dragonfly Nymphs with Dipteran 'Hitch-hikers': an Example of Phoresy Found in Dandenong Creek, *by Anneke Veenstra-Quah* 229

Acacia obtusifolia – Introduction and Spread in Native Bush, *by David Cheal* 231

The Discovery of Leadbeater's Possum *Gymnobelideus leadbeateri* along the Woori Yallock Creek, Yellingbo, *by Dan Harley* 233

Ooline *Cadellia pentastylis* F.Muell.: a Survivor, *by Ron Fletcher* 235

Foraminifera from Lake Corangamite, Victoria, *by Ken N Bell* 237

Naturalist in the Mountains

Winter Keeps Us Warm, *by Ken Green* 238

Snow in Spring, *by Ken Green* 240

Tribute

William Nigel Balcombe Quick, *by Michael F Braby and Charles McCubbin* 242

Book Reviews

Treasures from the Kingdom of Fungi, *by Taylor F Lockwood, reviewed by Simon H Lewis* 214

Butterflies of Australia: their Identification, Biology and Distribution, *by Michael F Braby, reviewed by Andrew Atkins* 244

Dragonflies of the World, *by Jill Silsby, reviewed by John Hawking* 245

Possums: The Brushtails, Ringtails and Greater Glider, *by Anne Kerle, reviewed by Ken Bell* 246

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Cover: Dragonfly *Aeshna* sp. – a representative of the invertebrates covered in this issue, e.g. dragonfly nymphs (p. 229) and dragonflies of the world (p. 245). Photo by Roger Gaymer.

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Seasonal and Altitudinal Differences in the Abundance and Species Richness of Some Flying Macroinvertebrates in Kosciuszko National Park, Australia

Michelle Stock[1] and Catherine Marina Pickering[1]

Abstract

Seasonal and altitudinal effects on invertebrate abundance and the diversity of flying macroinvertebrates, including potential pollinators, were examined at an alpine, subalpine and montane site in Kosciuszko National Park, Australia. Sampling using traps consisting of sticky white balls was conducted at four times during the growing/flowering season (between December and March). Only insects greater than 4 mm (macroinvertebrates) were identified. Of the total of 9011 invertebrates collected the most diverse and abundant macroinvertebrate taxa were Diptera. The next most abundant and diverse were the Hemiptera and Hymenoptera, with few Lepidoptera and Orthoptera. There were both seasonal and altitudinal effects, with the abundance and diversity of macroinvertebrates and Diptera (>4 mm) highest between December and February, corresponding to the main flowering periods. Abundance at all sites declined in March as temperatures declined. The abundance and diversity of macroinvertebrates in the alpine site was higher than expected compared to the montane site during the first three sampling periods. This differs from studies overseas that have found a decline in macroinvertebrate diversity and abundance with increasing altitude. (*The Victorian Naturalist* **119** (5), 2002, 216-221)

Introduction

Invertebrate diversity, abundance and activity have been found to decline with increasing altitude in mountain regions (Primack 1978; Arroyo *et al.* 1982, 1985; Inouye and Pyke 1988; Kearns 1992; Primack and Inouye 1993; Green 1997; Bingham 1998). This is thought to be due to the increasing severity of the environment, with lower temperatures, less biomass of vegetation, longer periods of snow cover, increased risk of frosts etc. at higher altitudes (Mani 1968; Arroyo *et al.* 1985; Inouye and Pyke 1988; Green and Osborne 1994). For example alpine areas are characterized by atmospheric cold, high atmospheric aridity, snow and ice, high ultraviolet radiation, large diurnal fluctuations in temperature, and rapid desiccation of delicate and soft-bodied organisms. These factors constrain the survival, growth and reproduction of invertebrates limiting their abundance and distribution in high altitude environments (Mani 1968; Arroyo *et al.* 1982, 1985; Green and Osborne 1994; Green 1997; Korner 1999).

Invertebrate abundance, activity and diversity can also vary seasonally in subalpine and alpine areas, including in the Australian Alps (Inouye and Pyke 1988; Green 1997). For example, very few Diptera and other flying insects overwinter in alpine areas with most either there accidentally (lifted by air currents), or migrating into the alpine for the summer, but returning to the lower areas to breed during winter (Mani 1968; Green and Osborne 1994). During the snow free period insect activity can vary with weather conditions, particularly temperature, and wind. This can result in seasonal and diurnal variation in the abundance and diversity of pollinators in alpine sites (Arroyo *et al.* 1985; Inouye and Pyke 1988; Bergman *et al.* 1996; Green 1997).

The most common type of insects in the alpine region of Kosciuszko National Park are Orthoptera (crickets and grasshoppers), Coleoptera (beetles), Hemiptera (bugs), Lepidoptera (butterflies and moths), Diptera (flies) and Collembola (springtails) (Inouye and Pyke 1988; Green and Osborne 1994; Green 1997). The main potential pollinators of the Kosciuszko alpine flora are thought to be the Diptera with 60 species visiting flowers (Inouye and Pyke 1988). Hymenoptera (33 species), along with several species of Lepidoptera and Coleoptera, were also found on flowers (Inouye and Pyke 1998). Unlike other alpine areas, there is a lack of social bees and other types of specialist pollinators in the Australian Alps and in New Zealand

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alpine areas matching an apparent lack of specialist pollination syndromes (Primack 1978; Inouye and Pyke 1988; Pickering 1997). The decline in the abundance and diversity of insect pollinators in subalpine and alpine environments is thought to have influenced pollination syndromes, timing of flowering and duration of stigmatic receptivity of alpine plants (Arroyo *et al.* 1982, 1985; Inouye and Pyke 1988; Kearns 1992; Totland 1993; Bergman *et al.* 1996; Bingham 1998; Pickering 1997; Korner 1999).

The aim of this study was to examine if altitude and seasonality affected the diversity and abundance of some flying macroinvertebrates in Kosciuszko National Park. It would be expected that the abundance of invertebrates including pollinators varies within a flowering season, with the highest abundance in the warmest months (January-February in Australia). Peak flowering in the alpine region of Kosciuszko National Park also occurs in the warmest months, although some species flower early in the season, soon after snow-melt or later in the season, often in March (Costin *et al.* 2000; pers. obs.). At lower altitudes insect numbers could peak earlier in the season during spring, when most plants are flowering. Numbers could also remain higher for longer, as temperatures are higher on average, and do not fall as fast late in the growing season (March-April; Green and Osborne 1994). It would also be expected that at higher altitudes macroinvertebrate activity/abundance would be lower than at subalpine or montane sites at any given time.

Methods

Study site

Macroinvertebrate diversity and abundance was sampled using passive traps consisting of white Styrofoam balls (11 cm diameter) coated in Tangle Trap® (modification of method by Prokopy 1968) attached to 2 mm diameter wire, with the balls positioned approximately 5 cm above the vegetation. Traps were placed at three altitudes in Kosciuszko National Park, New South Wales. The lowest altitude site was in the *Eucalyptus* woodland (montane vegetation zone) 1400 m ASL near Sawpit Creek. The next site was in subalpine heath near Prussian Creek below Smiggin Holes (1640 m ASL) and the final site was in tall alpine herbfield in the alpine region above Charlotte Pass Village on Mt Gutherie (1860 m ASL).

Sampling occurred four times during the flowering season. Initial sampling was on 18-20 December 1998 when all sites had been snow free for several weeks and temperatures were starting to increase. Sites were sampled again on 16-18 January 1999 at the peak of the alpine flowering season. The third sampling period was 1-3 February 1999 when flowering was declining at all sites. The final sampling was 27-29 March 1999 when flowering was finished and climatic conditions were less favorable for insect activity.

At each site one passive trap was randomly placed along each of five 30 m transects approximately 50 m apart. The traps were left for two days. Invertebrates greater than 4 mm in length were collected and identified to morphospecies in the field laboratory. It was not feasible to identify invertebrates less than 4 mm in the field laboratory.

Statistical analysis

Effects of altitude and season on species richness and abundance were examined by two-way analysis of variance using SPSS 10.00 (Coakes and Steed 2001). However, due to the relative lack of spatial dispersal of the traps at each altitude, the altitudinal effect must be interpreted with caution. To satisfy the assumptions of the analysis the total number of invertebrates, total number of Diptera, and number of invertebrates >4 mm data were transformed using a natural log $(x + 1)$ transformation. Tukeys post hoc test was used to compare means at each time and site.

Results

Diversity and abundance

A total of 9019 invertebrates was collected over the four sampling periods at the three sites. For macroinvertebrates (2490 >4 mm), the most common were Diptera (flies 69%; Table 1). The other groups of macroinvertebrates in decreasing abundance were Hemiptera (bugs ~11.5%), Hymenoptera (bees and wasps ~11%), Lepidoptera (moths ~4%), Orthoptera (grasshoppers ~4%), Blattodea (cockroach-

es – less than 1%), Arachnida (spiders – less than 1%) and Coleoptera (beetles – less than 1%). Approximately 76% of the invertebrates caught were smaller than 4 mm (Table 1) and were not identified.

Diptera were the most diverse macroinvertebrates as well as the most abundant (Table 2). There were 31 morphotaxa representing at least 10 families. Hymenoptera were represented by three bee morphotaxa and four wasp morphotaxa. Within the Lepidoptera there were five morphotaxa, with at least one representative of the Oecophoridae, Geometridae and Noctuidae families. There were four Orthoptera morphotaxa, one type of Blattodea, one type of Coleoptera, and two types of Hemiptera.

Effect of altitude and time

The total number of invertebrates varied seasonally at each of the three altitudes with a clear decline in invertebrate numbers in March compared to earlier in the season (Fig. 1). There were significantly more invertebrates collected in December in the alpine site than at any other time at any altitude (Fig. 1; two-way ANOVA, effect of time by altitude interaction, $df = 6$, $F = 19.819$, $p < 0.001$). The peak number of invertebrates was highest in January for both the subalpine and montane sites.

The data for just the small invertebrates (less than 4 mm) showed the same pattern as for total invertebrates. The largest number of invertebrates was found on traps in the alpine site in December, and there was a decrease in the number of invertebrates caught at the three altitudes in March (Table 3; two-way ANOVA, effect of time by altitude interaction, $df = 6$, $F = 12.733$, $p < 0.001$).

The data for Diptera only also showed the same pattern. There was a significant interaction between altitudes and times (Table 4; two-way ANOVA, effect of time by altitude interaction, $df = 6$, $F = 6.378$, $p < 0.001$). The number of Diptera also declined dramatically in March at all altitudes (Table 4).

There was considerable variation in diversity of macroinvertebrates at the different altitudes and times (Fig. 2; two-way ANOVA, effect of time by altitude interaction, $df = 6$, $F = 3.835$, $p = 0.003$). All three altitudes showed a relatively constant number of morphospecies between December and February, with a clear decrease in March (Fig. 2).

Table 1. Number of invertebrates belonging to different orders trapped at the three altitudes (montane, subalpine and alpine sites) in Kosciuszko National Park during the 1998/1999 growing/flowering season.

Invertebrate order	Total number	% all invert.	% > 4 mm
Micro- and meso-invertebrates	6931	76.85	
Diptera	1432	15.88	68.58
Hemiptera	240	2.66	11.49
Hymenoptera	226	2.51	10.82
Lepidoptera	87	0.96	4.17
Orthoptera	84	0.93	4.02
Blattodea	10	0.11	0.48
Arachnidae	8	0.09	0:38
Coleoptera	1	0.01	
Total	**9019**		

Discussion

The abundance and diversity of invertebrates was lower at the end of the growing/flowering season in March than in December and January at all three alti-

Table 2. Diversity of insects trapped at the three altitudes during the 1998/1999 flowering season at Kosciuszko National Park.

Order	Family	No. morphotaxa
Diptera	Total	31
	Muscidae	1
	Tachinidae	3
	Calliphoridae	4
	Syrphidae	1
	Tabanidae	3
	Asilidae	2
	Tipulidae	1
	Simulidae	1
	Tephritidae	1
	Culicidae	1
	Unknown	13
Hymenoptera	Total	7
	Anthophoridae	2
	Ichneumonidae	1
	Unknown	4
Lepidoptera	Total	5
	Oecophoridae	1
	Geometridae	1
	Noctuidae	1
	Unknown	2
Orthoptera	Total	4
	Acrididae	1
	Pyrgomorphidae	2
Blattodea	Total	1
Coleoptera	Total	1
	Cleridae	1
Hemiptera	Total	2
	Cicadidae	1
	Unknown	1

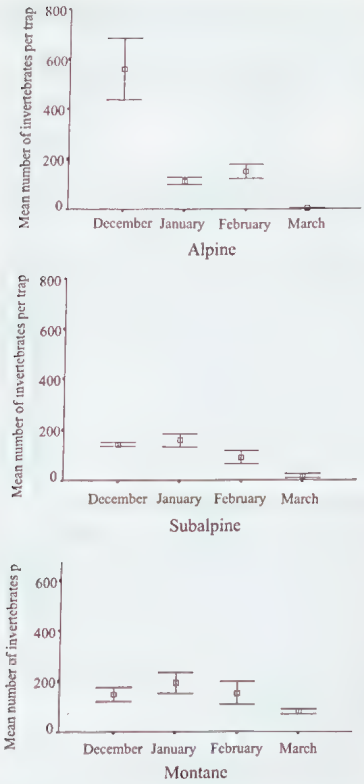

Fig. 1. Mean and standard error of the total number of macroinvertebrates per trap at four times during the flowering season at three altitudes in Kosciuszko National Park.

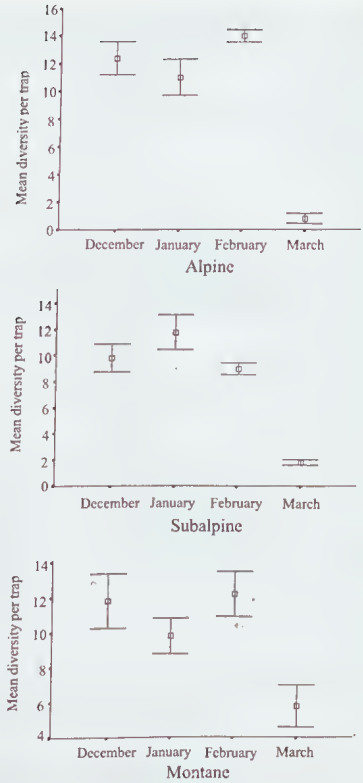

Fig. 2. Mean and standard error of the diversity of macroinvertebrates per trap at four times during the flowering season at three altitudes in Kosciuszko National Park.

tudes. This pattern is consistent with other studies in alpine and subalpine sites in Kosciuszko National Park that used different sampling methodologies (Inouye and Pyke 1988; Green 1997), as well as with studies of alpine and subalpine environments elsewhere in the world (Arroyo *et al.* 1982, 1985; Primack and Inouye 1993; Bergman *et al.* 1996; Bingham 1998). The reduction in invertebrate numbers in March is likely to be due to factors such as lower temperatures at the end of the flowering season. Factors such as temperature, wind speed and light levels have all been found to affect insect activity, including in sites close to those used in this study (Primack 1978; Arroyo *et al.* 1985; Inouye and Pyke 1988; Primack and Inouye 1993; Bergman *et al.* 1996). These changes in invertebrate numbers are likely to affect the potential for insect pollination for those few alpine plants that flower late in the season (Arroyo *et al.* 1985; Inouye and Pyke 1988; Primack and Inouye 1993; Bergman *et al.* 1996). The bulk of the flowering in the Kosciuszko alpine occurred in December and January, when macroinvertebrate diversity was high. By March, however, when only a few species were flowering (e.g. Mueller's Snow-gentian *Chionogentias muelleriana*), most plants had finished releasing their seeds and insect diversity had decreased to only one morphospecies (a hymenopteran).

The high abundance and diversity of macro-Diptera compared to other orders of macroinvertebrates found in this study are consistent with observations in nearby sites. Diptera were the most diverse (31 species, at least 10 families) and abundant

Table 3. Mean (and standard error) of the number of <4 mm invertebrates trapped at each sampling period at alpine, subalpine and montane sites.

Sampling date	Alpine	Subalpine	Montane	Total
20 December 1998	469 ± 109	112 ± 8	110 ±18	230 ± 57
18 January 1999	73 ± 14	120 ± 24	166 ± 46	120 ± 19
3 February 1999	31 ± 18	66 ± 24	121 ± 43	82 ± 18
29 March 1999	2 ± 1	15 ± 8	72 ± 9	34 ± 10
Total	**168 ± 54**	**78 ± 13**	**117 ± 17**	**120 ± 19**

Table 4. Mean (and standard error) of the number of Diptera trapped at each sampling period at alpine, subalpine and montane sites.

Sampling date	Alpine	Subalpine	Montane	Total
20 December 1998	75 ± 27	14 ± 3	34 ± 10	41 ± 11
18 January 1999	29 ± 3	31 ± 7	23 ± 7	28 ± 3
3 February 1999	27 ± 6	19 ± 5	24 ± 5	23 ± 3
29 March 1999	0	1.4 ± 1	9 ± 2	3 ± 1
Total	**33 ± 10**	**16 ± 3**	**22 ± 4**	**24 ± 3**

taxa (69% of insects greater than 4 mm) in the study presented here. Inouye and Pyke (1988) also found that Diptera were the most abundant and diverse flower visitor, with a total of 60 species of Diptera, belonging to 18 families visiting flowers from a range of species. The most abundant flower visitors were Diptera, accounting for 62.3% of flower visitors, followed by Hymenoptera (30.8% flower visitors), then Lepidoptera (11.2%) and Coleoptera (1.9%) (Inouye and Pyke 1988).

Several studies have shown that species richness decreases with increasing altitude (Mani 1968; Arroyo *et al.* 1985; Primack and Inouye 1993; Green 1997; Bingham 1998). From this, it was expected that there would be a greater diversity of taxa in the montane site, than the alpine and subalpine sites. This was not the case. Overall there were forty-three morphospecies of macroinvertebrates in the alpine, thirty-three in the subalpine and forty in the montane site. In addition, during peak flowering in the alpine, there were either more or similar numbers and diversity of macroinvertebrates than in the subalpine and montane sites. Therefore, it could be that there are quite high numbers of macroinvertebrates, particularly Diptera, available to act as pollinators at the time of peak flowering in the alpine. The results obtained in this study should be viewed with some caution, as they could be due to site specific factors, and hence may not be representative of a general trend with altitude. Also, the diversity data only applies to insects greater than 4 mm and hence does not reflect total invertebrate diversity.

The relative dominance of Diptera amongst alpine insect fauna, particularly among potential pollinator suites, has been found in a range of alpine regions (Inouye and Pyke 1988; Kearns 1992; Totland 1993). It is thought, in part, to be due to Diptera numbers not declining, or not declining as fast with increasing altitude as the abundance and diversity of other insect groups, such as bees (Primack 1978; Arroyo *et al.* 1982, 1985; Kearns 1993). For example, the diversity of Diptera was higher at high and mid elevations than at low elevations in study across an altitudinal gradient in the Rocky Mountains, USA (Kearns 1992). The abundance of Diptera did not decline with increasing altitude, unlike other groups of insects (Kearns 1993), resulting in the increasing importance of Diptera as pollinators at higher altitude. Similar patterns have been found in some other alpine regions (Primack and Inouye 1993; Totland 1993) with Diptera abundance and diversity found to be fairly constant or declining more slowly across altitudinal gradient. The effect of this is that at higher elevations, which often have fewer bees and other specialized pollinators, Diptera were most common (Arroyo *et al.* 1982; Primack and Inouye 1993). In the study presented here, Diptera were also found to be the most diverse and abundant insects in the alpine zone, adding support to their prominence as potential pollinators in such environments.

Acknowledgements
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Observations on the Feeding Behaviour of Uchidanurinae (Collembola: Neanuridae) in Australia

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Abstract
Two observations of feeding on the plasmodial stage of a slime mould (Mycetozoa) in *Eucalyptus* forest in Victoria and Tasmania by species of the log-inhabiting Uchidanurinae are documented. It is suggested that feeding on Protozoa may be much more common in members of the Neanuridae than is currently considered. The Uchidanurinae are of conservation significance as they tend to be inhabitants of old growth vegetation, highly diverse in south-eastern Australia and Tasmania and very susceptible to human impacts. (*The Victorian Naturalist* **119** (5), 2002, 221-223)

Introduction

The Uchidanurinae are among the largest and most spectacular Collembola. Individuals may be up to 10 mm long and are dark blue, grey or black with a flattened, segmented body furnished with lobes and digitations often conspicuously tipped with orange or yellow. The animals live in or under old decaying logs in old growth forests or in heathland undisturbed by fire for long periods, and unlike most other Collembola, lack a jumping organ. Although only three Australian species have been described so far, collections from south-east Australia and Tasmania indicate that about thirty species can be distinguished on gross morphology and it is likely that a much larger number of cryptic species exist (Greenslade 1991, 1993). The subfamily is also found in New Zealand, New Caledonia and parts of south-east Asia and is considered to be Gondwanan in origin (Greenslade 1991).

Based on their mouthparts, Collembola can be divided into two groups. The first group possesses a mandible with a toothed molar plate while the second group has a simpler mandible without a toothed molar plate. Observations made on easily cultured species from families belonging to the first

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group suggest that Collembola have relatively unspecialised feeding habitats and consume fungi, bacteria and other microorganisms, with some preferences for certain fungal species, possibly based on nutritional value (Hopkins 1997). However, by definition, easily cultured species are likely to show relatively generalised feeding preferences so the unspecific nature of feeding habits may not be as widespread as these observations indicate (Greenslade 1993).

Families lacking the molar plate, such as the Neanuridae to which the Uchidanurinae belong, show a greater morphological variation in mouth parts, suggesting that a range of specialised feeding habits may be a characteristic of this group. It is known that several species of Neanurinae, a closely related subfamily, have been kept alive for long periods as long as temperatures are kept low and moisture regimes high, but feeding and reproductive behaviour were never observed in culture (L Deharveng pers. comm.). The Uchidanurinae are typical of the Neanurinae in that individuals have been kept at a temperature of 4°C for over five months, but feeding on microorganisms such as bacteria, yeasts or fungi was never observed nor were any eggs seen (P Greenslade pers. obs.). In addition, studies of the alimentary canals of Neanurinae have failed to find any identifiable contents (L Deharveng pers. comm.).

Observations

Two independent observations in the field have been made of Uchidanurinae feeding in natural undisturbed environments. In both cases a number of individuals were observed during the day feeding on the plasmodial stage of a yellow slime mould, probably *Fuligo septica*. The first observation was made by R. Farrow in tall wet sclerophyll forest in the Florentine Valley, southwest Tasmania, in February 1992. Farrow photographed two individuals apparently feeding on a conspicuous yellow slime mould growing on the lower side of a well-rotted log, possibly of a *Eucalyptus* species, in deep shade about midmorning. The second set of observations were made by S Moore on both the 29 July, 2001 and the 5 August, 2001, at the same site in semi-open eucalypt forest in Kinglake National Park, northeast of Melbourne, Victoria. These animals were feeding on the slime mould growing on the outside of a rotting log, possibly *Acacia* sp., in eucalypt forest with an understorey of bracken *Pteridium esculentum*. Again, the observations were made during the day. On the first occasion, two individuals were noted at 2 pm feeding in overcast, calm and wet conditions at a temperature of approximately 12°C. On the second occasion, ten individuals were observed at 10 am in overcast, calm and damp conditions at a temperature of approximately 8°C. This site was extremely humid, being adjacent to a rainforest gully. Photographic records of both observations were made and specimens were collected, The two species were different and belonged to two different available genera in the Uchidanurinae. The Tasmanian species belonged to *Acanthanura* sp. cf. *dendyi* (Lubbock 1899) and the Victorian species to *Womersleymeria* sp. *bicornis* group (Womersley 1940), but cannot be identified further until a revision of the subfamily in Australia can be carried out.

Specimens of both slime mould and Collembola from the Kinglake National Park were retained for examination in culture but proved difficult to observe under a normal microscope light.

Discussion

Slime moulds are found on shed bark, well-rotted logs and in leaf litter, mainly in moist environments. They are most easily cultured from cut bark and survive desiccation and rehydration (Stephenson and Stempen 1994). All collections of Uchidanurinae from forests have been made from similar habitats, that is either within or under logs or in leaf litter with an abundant bark content. Individuals are usually collected from just under bark on logs or between bark and the thick layer of moss growing on it.

Slime moulds were, in the past, considered to be closely related to fungi, as indicated by the scientific name, Myxomycetes. However they are now considered to have a closer relationship and ancient ancestry with Protozoa, and are more correctly referred to as Mycetozoa (Wheeler 1984). Although soil Protozoa have sometimes been recorded as food of Collembola there have been no direct data to support the suggestion. In

fact, reviews of feeding in Collembola usually fail to mention Protozoa (Christiansen 1964) or mention them but give no supporting reference (Rusek 1998). Andren and Schnurer (1985) assume Protozoa constitute a considerable proportion of the diet of *Folsomia fimetaria* (Isotomidae), as only a small percentage of the animals' growth could be accounted for by fungi, but direct evidence was lacking. Although Ing (1967) recorded adventitious Collembola probably feeding on slime moulds in culture, the only published observation of an identified collembolan species feeding on the plasmodial stage of Mycetozoa is that of Chassain (1973). He observed feeding of *Neanura muscorum* Templeton (Neanuridae: Neanurinae) on two species of slime moulds, *Dictydiaethalium plumbeum* Rost and *Trichia varia* (Pers.). Chassain (1973) also noted that when the slime mould transforms to the sporulation phase, some Collembola become trapped and die. A number of other organisms, Coleoptera, Diptera and Acari (Blackwell 1984; Wheeler 1984; Lawrence and Milner 1996) have been reported as forming an association with slime moulds (Frederick 1990) but rarely with the plasmodial stage since most species feed on mature sporocarps.

The Uchidanurinae are nearly all heavily pigmented and have eight ocelli on each side of the head. This is suggestive of diurnal activity in these organisms as nocturnal species normally have reduced ocelli and reduced pigment of the body. However, foraging during the day of cryptic, humid log-inhabiting species might not be expected because these animals would be vulnerable to the lower humidities found outside the log habitat. It is significant that the diurnal activity recorded here was at a time when light intensity in these forests was low and at sites where humidities were particularly high. Observations have also been made of a different species foraging during the day on the surface of a rotting log in rainforest at Cooloola National Park, Queensland (P Greenslade pers. obs.).

We suggest that as all members of the subfamily Uchidanurinae have very similar mouthparts, they may be specialist feeders on slime moulds. This would explain not only the observations recorded here, but also the difficulty of culturing these animals and also explain their preferred habitat under the bark of rotting logs. Moreover, the literature indicates that the feeding habitats of the family Neanuridae are still unknown because identifiable gut contents are not normally observed in mounted specimens. Our observations, together with those of Chassain (1973), indicate that it is possible that other members of the family Neanuridae may also show a preference for or feed exclusively on slime moulds and perhaps even more commonly on other Protozoa.

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Butterfly Management Uses Pollard Walk

Bryan T Haywood[1] and Christopher J Wilson[2]

Abstract

South Australia's first set of butterfly walks was conducted in the Penambol Conservation Park from 13 November 2000 to 25 April 2001. A simple survey technique devised by Pollard (1977) was used to record the changes in abundance of common and rare butterflies during a weekly transect walk. Ten butterfly species were recorded during the survey period with 4 species being regionally threatened species. The survey technique has great relevance for the survey and management of threatened species in many terrestial environments with the assistance of volunteers also important for its success. The presence and absence of particular species in specific habitats can also be objectively used as a guide to overall habitat health and condition. (*The Victorian Naturalist* **119** (5), 2002, 224-226)

Introduction

A simple survey technique to observe and record the abundance in butterfly fauna was devised by Pollard (1977) as a method for assessing the changes in the abundance of butterflies. The method was first developed at Monks Wood Experimental Station (UK) to enable a person (with relatively little experience) to assess the changes in abundance of butterflies in their locality. Endersby (1994) and Brooks (1993) highlighted the use of the Pollard walk for counting insects, especially dragonflies, suggesting minor modifications to reflect local conditions but overall finding the technique repeatable and very effective. Staff of the Department for Environment and Heritage (DEH) in South Australia, with the assistance of local volunteers, want to further highlight the suitability of the Pollard walk as a tool for the management of butterfly species and as a component in assessing remnant vegetation health.

The Pollard walk, 'the first of its kind in South Australia,' was initiated in 2000/01 and is being used for surveying butterflies in the Penambol Conservation Park, South Australia, a 178 hectare reserve situated 25 km south-east of Mount Gambier in an area more commonly known as Caroline Forest.

The aim of the survey was to:

- highlight the simplicity of monitoring a site for butterflies using the Pollard walk;
- commence the first annual Butterfly walk for South Australia;
- record the numbers and species of Lepidoptera present in the Penambol Conservation Park;
- encourage local volunteers to be involved;
- use the information collected on butterfly presence as a guide to the assessment of a habitat's health and condition.

Fisher (1983) and Grund and Hunt (1997, 2000) have previously recorded the butterfly fauna in the Lower South East including the Penambol Conservation Park area. They determined the locality as one of great potential for the discovery of various species occuring in Victoria but rare in this region. This is principally due to the fact that the Lower South East of South Australia is the westerly extension of habitats (and the range of flora and fauna species) occuring throughout south-eastern Australia.

The habitat throughout the transect included Messmate Stringybark *Eucalyptus obliqua* on deep sandy soil, Swamp Gum *E. ovata* on red loam over limestone, open cleared ground of Bracken *Pteridium esculentum* with emergent *E. obliqua* over introduced grasses and weeds, and Blackwood *Acacia melanoxylon* over Mat Rush *Lomandra longifolia*.

Method

The Pollard walk suitably should be undertaken from Spring to Autumn each year (Pollard 1977). As this was the first year of the walk the authors began the survey from 13 November 2000 and ended on 25 April 2001. Each week during this period a walk was undertaken along a fixed and segmented transect (between 1100 and

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1600 hours). Pollard (1977) stressed the importance of undertaking a walk during optimum conditions. The weather can have considerable effect on the numbers of butterflies seen. Therefore before each survey the temperature, approximate wind speed (Beaufort Scale) and direction and cloud cover (sunshine) were recorded. Any day during the allocated week could be chosen for the Pollard walk to allow for the best conditions. Each walk was completed at a slow pace and took on average 25 min. The walk was divided into 7 sections with each section reflecting a change in habitat. All butterfly species seen were identified and counted at a distance up to 10 m in each of the seven sections. Any un-identifiable butterflies were recorded as such and/or caught and later identified using Braby (2000) and/or Fisher (1978). Some uncommon and rare species were taken as specimens, mounted, labelled and stored at the Mount Gambier DEH office invertebrate collection for future reference. Notes were also taken relating to general observations, feeding plants and other fauna sighted during each walk. All data recorded were entered into a spreadsheet and forwarded to the Biological Survey and Research section of the Department for Environment and Heritage.

The habitat was assessed using a habitat assessment technique developed for the Property Management Planning program (Primary Industries South Australia 1997). The assessment process was to answer a number of simple questions as to the presence and/or absence of various natural features of a habitat of that type and associated wildlife. The assessment included the allocation of points for positive and negative features contained within the habitat. For example the presence of understorey plants especially grasses would receive 5 points and the presence of weeds would receive 5 minus points and so on. The tally at the end of the exercise would provide an assessment of the habitat depending on the score.

Results

In 2000/01 a total of 10 species was recorded along the weekly walks (Table 1). The most commonly recorded butterflies were the Common Brown *Heteronympha merope merope*, Common Grass Blue *Zizina labradus labradus* and the Klug's Xenica *Geitoneura klugii*. The graph

Table 1. Butterfly species recorded including conservation status for South Australia (South Australian Butterflies 1998). SA conservation ratings: U, uncommon; R, rare.

Common Name	Scientific Name	Conservation Status
Australian Admiral	*Vanessa itea*	
Australian Painted Lady	*Vanessa kershawi*	
Barred Grass-skipper	*Dispar compacta*	U
Bright Shield-skipper	*Signeta flammeata*	R
Cabbage White	*Pieris rapae rapae*	
Common Brown	*Heteronympha merope merope*	
Common Grass Blue	*Zizina labradus labradus*	
Klug's Xenica	*Geitoneura klugii*	
Shouldered Brown	*Heteronympha penelope penelope*	U
White-banded Grass-dart	*Taractrocera papyria papyria*	R

Table 2. Habitat assessment for each section of the walk showing the presence of rare and common species and total butterfly numbers recorded for each section during survey period.

Section	Habitat Value	Number of rare species	Number of common species	Total numbers
1	High	3	5	517
2	Low	1	5	86
3	Moderate	3	5	230
4	Low	2	6	93
5	Low	0	2	106
6	Moderate	1	5	155
7	High	2	5	377

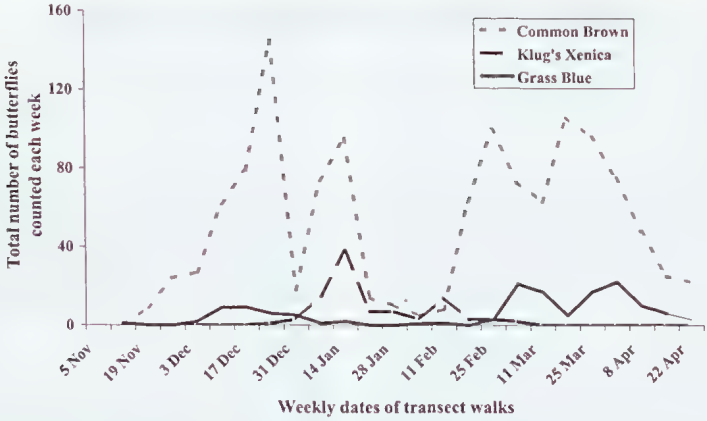

Fig. 1. The abundance of the three most common species recorded throughout the Pollard walk displaying the total for each week.

shows the abundance of these three species each week during the walk (Fig. 1).

The sections of the walk that received a low habitat score had fewer butterflies and/or rare species recorded. Those common species recorded in these sections were normally seen in open impoverished habitats. The areas with moderate/high habitat value recorded a greater diversity and abundance including most species of conservation significance (Table 2).

Conclusion

Initial findings indicated that data collected using the Pollard walk could assist in identifying variations in the presence of rare/threatened populations of butterflies at a site. The long term trends of any monitoring program are critical to the actions undertaken for rare/threatened species especially if the technique for the collection of data can be simplified. Pollard (1977) offers such a technique for scientific authorities and professionals, amateur entomologists or nature enthusiasts. The contribution and assistance offered by volunteers is also a critical component to the success of a wildlife monitoring program like the Pollard walk.

The presence of rare species in some sections of the walk indicates that the habitat is of moderate/high biodiversity value. The areas of the walk in which few butterfly species were found could be an indication that the habitat is impoverished and needs attention. However with only one year's data this conclusion cannot be substantiated.

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First Record of the Asian Freshwater Leech *Barbronia weberi* (Blanchard, 1897) (Euhirudinea: Erpobdellidae) in Australia

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Abstract

Two individual *Barbronia weberi*, an invasive species from India and southeast Asia, were collected from Common Waterweed *Hydrilla verticillata* purchased in June, 2001 from an aquarium supplier in Melbourne, Australia. Adult leeches were fed *Tubifex* sp. *ad libitum* and successfully reproduced under laboratory conditions (21°C). This invasive species has the potential to adversely affect the biodiversity of native Australian freshwater invertebrates and the extent of this invasion is not clearly known. (*The Victorian Naturalist* **119** (5), 2002, 227-228)

Introduction

Members of the family Erpobdellidae are typically freshwater predators feeding on a range of invertebrate prey including crustaceans, insects, molluscs, and annelids. Unlike their bloodsucking cousins, these leeches lack both a proboscis and jaws and often feed by swallowing their prey whole. Erpobdellids are well known for being important sit-and-wait predators in aquatic ecosystems, with a few species being pelagic predators in the absence of fish (Blinn *et al.* 1987). In addition, erpobdellids may be important prey for vertebrate and invertebrate predators (Sawyer 1986; Davies and Govedich 2001).

Barbronia weberi (Blanchard, 1897) was originally described from India and is native to south-east Asia, Java, Sumatra, Celebes, Borneo, Philippines and Afghanistan (Sawyer 1986; Soós 1966; Nesemann and Sharma 1996). It has been introduced to New Zealand, England, Brazil, and the United States of America, apparently through the aquarium trade (Mason 1976; Sawyer 1986; Pamplin and Rocha 2000; Rutter and Klemm 2001). *Barbronia weberi* is often associated with aquatic vegetation, using aquatic plants as a substrate for attachment and for the attachment of cocoons, and it is likely this species has been transported with common aquarium plants, *Hydrilla verticillata* (Linnaeus, 1782) and *Elodea* sp.

Methods

Two reproductively mature leeches were found on *Hydrilla verticillata* purchased (June, 2001) from an aquarium supplier in Melbourne, Australia. The adult leeches were fed *Tubifex* sp. *ad libitum* and maintained in 200 ml of artificial pond water (pH = 6.96, conductivity = 31.6 µS, 21°C) for 3 months. Following the production of cocoons the adults were preserved in 70% ethanol and examined using an Olympus SZH-10 dissecting microscope to determine their identity.

Results and Discussion

Barbronia weberi is distinguishable from two superficially similar Australian erpobdellids, *Vivabdella arcana* Richardson, 1970 and *Dineta cylindrica* Goddard, 1908. Both *B. weberi* and *V. arcana* have three pairs of eyes and accessory copulatory pores (Fig. 1d) distinguishing them from *D. cylindrica* which has four pairs of eyes and lacks accessory pores (Fig. 1c). *Barbronia weberi* can be distinguished from *V. arcana* (Fig. 1a, f) based on the presence of pharyngeal stylets (Fig. 1b) and the absence of simple postcaeca (Fig. 1e).

Each adult *Barbronia weberi* produced between 8 and 10 cocoons during a two week period and each cocoon was attached to solid substrates (aquatic vegetation, rocks or the sides of aquaria). Cocoons were produced every other day over the two weeks and each cocoon contained two or three small eggs surrounded by transparent fluid. Upon hatching the young were 5.6 ± 0.6 mm long and 0.7 ± 0.2 mm wide (relaxed), capable of feeding independently on *Tubifex* sp. and became reproductively mature within four months of hatching (n = 7). At reproductive maturity, leeches had a relaxed length of 21.5 ± 3 mm and width of 2.3 ± 0.3 mm (n = 11).

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Adult *Barbronia weberi* were found attached to *Hydrilla verticillata*, a weedy aquatic plant that has been known to invade freshwater ecosystems. The leeches were usually attached near the base of the leaf whorls or along the stem, making them difficult to see. While most of the individual cocoons were attached to the bottom or sides of the container, some of the cocoons were laid on individual leaves. All cocoons, regardless of attachment site, eventually hatched. Both the behaviour of the parent and the attachment of cocoons to *H. verticillata* allow this species to be transported as both an adult and as a cocoon. This close association, at both the cocoon and adult stages, has allowed *B. weberi* to successfully invade many new areas via the aquarium trade (Mason 1976; Sawyer 1986; Pamplin and Rocha 2000; Rutter and Klemm 2001).

The *H. verticillata* which contained the *B. weberi* had been part of a shipment that originated from a pool of locally (Melbourne) and nationally grown plants making it difficult to identify the source of the *B. weberi*. However, all stocks of the *H. verticillata* were from Australian sources, indicating that *B. weberi* has been and is being maintained in the Australian aquarium trade. When placed into an aquarium with a gravel base, individual leeches were observed to burrow into the gravel, making them virtually undetectable. Like other erpobdellid leeches, *B. weberi* is an aquatic predator that swallows its invertebrate prey (insects, worms, etc.) whole. Being a predator with rapid development and the ability for adults and cocoons to be transported in aquatic vegetation, allows *B. weberi* to invade new systems where they have the potential to compete with or feed on native invertebrate species. The introduction of this invasive species could potentially have long term consequences for the biodiversity and survival of native Australian freshwater fauna and the ecosystems they inhabit. Unfortunately it is not clear how many *B. weberi* are in Australia, or the extent of the invasion of Australian aquatic systems, and further studies need to be completed to determine the extent and effect this species is having in Australia.

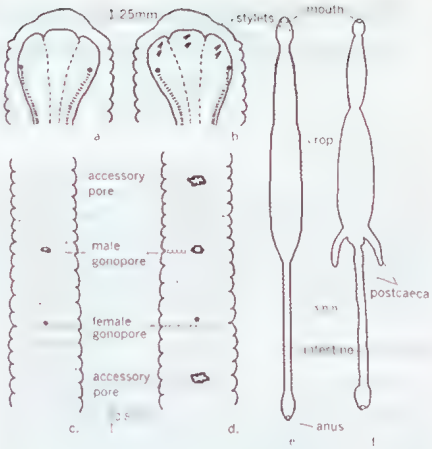

Fig. 1. Morphological features of *Barbronia weberi* and *Vivabdella arcana*. Top left: Dissected view of the buccal cavity of *V. arcana* (a), without stylets and *B. weberi* (b) containing stylets. Bottom left: External view showing the gonopores of a typical erpobdellid (c) and the gonopores and accessory copulatory pores of *B. weberi* and *V. arcana* (d). Right: Digestive system of *B. weberi* (e) without postcaeca and *V. arcana* (f) with postcaeca.

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Dragonfly Nymphs with Dipteran 'Hitch-hikers': an Example of Phoresy Found in Dandenong Creek

Anneke Veenstra-Quah[1]

Abstract
A phoretic association was observed between larvae of *Rheotanytarsus juliae* (Diptera: Chironomidae) and larvae of *Austroaeschna unicornis unicornis* (Odonata: Aeshnidae) collected from one site near the headwaters of Dandenong Creek, Victoria. (*The Victorian Naturalist* **119** (5), 2002, 229-231)

Introduction

Phoresy, from the Greek *phoresis*, 'a carrying', is a phenomenon where an individual of one species is transported by an individual of another species (Gullan and Cranston 1994). Phoresy has been observed in freshwater ecosystems where small or slow-moving animals rely on larger more mobile species for transport. There have been numerous overseas reports of dipteran larvae, particularly non-biting midges from the Family Chironomidae, attaching themselves to several insect orders including Ephemeroptera (White *et al.* 1980; Tokeshi 1986), Plecoptera (Bottorff and Knight 1987), and Odonata (Rosenberg 1972; White *et al.* 1980; Dudgeon 1989). Hawking and Watson (1990) reported the first association between larvae from the chironomid genus *Rheotanytarsus* and the dragonfly *Austroaeschna atrata* in Australian waters.

Chironomid larvae are popular prey items for many predators, and increasing their effective size by attaching to a larger organism like a dragonfly nymph can decrease the potential number of predators capable of feeding on them (Tokeshi 1995). A phoretic association has now been observed between *Rheotanytarsus juliae* (Diptera: Chironomidae) and *Austroaeschna unicornis unicornis* (Odonata: Aeshnidae) collected from the headwaters of Dandenong Creek.

Rheotanytarsus is a widespread, tube-building genus found in flowing water (Cranston 1996). Their distinctive non-transportable cases constructed of detrital and algal material, have arm-like extensions on which the larva spins a silken web for filtering fine food particles carried by the current. *Rheotanytarsus juliae* is the most abundant species in cool temperate regions of south-eastern Australia (Cranston 1997).

Austroaeschna unicornis unicornis nymphs are ambush predators, inhabiting mud or gravel substrates, crevices in rocks and logs, in both montane and lowland streams in south-eastern Australia (Hawking 1986). *Austroaeschna* nymphs have slow growth rates, hard cuticles with many sites suitable for attachment, and they remain stationary for long periods in mud and detritus, habitats favoured by chironomids (Hawking and Watson 1990).

Methods

The headwaters of Dandenong Creek upstream of Edgar Track in Doongalla State Forest 37° 51' S, 145°20' E were sampled using the rapid bioassessment method of Tiller and Metzling (1998) on 30 August 2001. At this site, the streambed was comprised of small boulders and cobbles with large amounts of detritus present. Tree ferns and eucalypts dominated the riparian zone vegetation (Fig. 1).

Invertebrates were collected by kick sampling for five minutes using a collecting net with mesh size 250 µm, live sorted in the field, preserved in 70% ethanol, and initially identified to family level in the laboratory using published keys. Dragonfly nymphs were later identified to species level using Hawking (1986) and chironomids to species level using Cranston (1996, 1997).

Results

Of the five *A. unicornis unicornis* nymphs collected from this site on Dandenong Creek, two had larval *R. juliae* attached. Two chironomid larvae were associated with the largest dragonfly nymph – one attached

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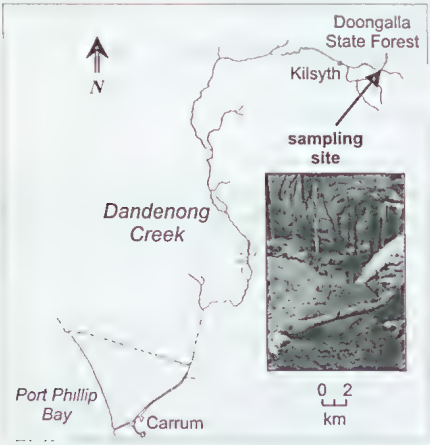

Fig. 1. Location and photograph of the sampling site near the headwaters of Dandenong Creek upstream of Edgar Track in Doongalla State Forest.

Fig. 2. Two *Rheotanytarsus juliae* larvae associated with *Austroaeschna unicornis unicornis* the largest dragonfly nymph collected - one attached horizontally to the tibia of the hind leg (black arrow and inset) and the other near the wing pad margin (white arrow).

horizontally to the tibia of the hind leg and the other near the wing pad margin (Fig. 2). The other nymph had a single case attached laterally to the first abdominal segment.

Discussion

The phoretic association between aeshnid dragonfly nymphs and chironomid larvae is thought to be quite common (JH Hawking 2001 pers. comm.). The headwaters of Dandenong Creek have been sampled since the late 1970s (Campbell 1978; Nuttall 1982; Ferdinands *et al.* 1995) and dragonfly nymphs from the family Aeshnidae have often been collected in the vicinity of the site sampled in August 2001. However, there are no published records of chironomids attached to aeshnid nymphs. This may be because the association was not noticed when samples were sorted due to the fact that the nymphs are dark brown in colour, often covered in detritus and the brown *Rheotanytarsus* cases may be easily overlooked.

It is interesting to note that of the 41 *A. atrata* nymphs collected by Hawking and Watson (1990) from two sites in the upper catchment of the Kiewa River, only two had *Rheotanytarsus* attached, compared with five *A. unicornis unicornis* nymphs collected from the headwaters of Dandenong Creek and two of which had *Rheotanytarsus juliae* attached.

Acknowledgements

I would like to thank Helen Madden for the excellent dragonfly nymph portrait, Suzanne Kiss von Soly, for her kick-sampling expertise, Rebecca Joyce, an observant student who noticed that there was something unusual about one dragonfly nymph, and other students from the School of Ecology and Environment (Deakin University) Freshwater Biology class – Louise Biggs, Katie Christopher, Rebecca Pretty, Jacqueline Rosewall and Haylee Weaver.

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Acacia obtusifolia – Introduction and Spread in Native Bush

David Cheal[1]

Abstract

Acacia obtusifolia has reproduced and expanded from a single introduction in the upper Yarra Valley in native bush as a result of inadvertent introduction of seed on earth-moving equipment. Initial establishment was dependent on soil disturbance, but subsequent spread has been episodic and dependent on fire-promoted germination and establishment. There is no evidence of seed germination and establishment in the absence of fires. The next fire may lead to a dramatic increase in both the number of *A. obtusifolia* plants and their local distribution. (*The Victorian Naturalist* **119** (5), 2002, 231-232)

Many native species have spread from their former habitats following European settlement. In south-eastern Australia some of the most troublesome include *Acacia longifolia* (Jameson 1994), *Leptospermum laevigatum* (Burrell 1981; Molnar *et al.* 1989; Offor 1990) and *Pittosporum undulatum* (Gleadow and Ashton 1981; Gleadow 1982), but many others have been occasionally recorded as weeds or as the product of recent human-assisted spread (see Walsh and Entwisle 1994; Walsh and Entwisle 1996; Low 1999; Walsh and Entwisle 1999).

Acacia obtusifolia is a tall wattle characteristically found on the slopes and low ridges of drier East Gippsland forests (Walsh and Entwisle 1996). However, the Flora Information System of the Department of Natural Resources and Environment, Victoria, has an isolated record from the Upper Yarra Valley, much closer to Melbourne and approximately 160 km from the nearest Gippsland record (see Walsh and Entwisle 1996: 597). This small stand is an example of recent, human-assisted spread rather than a natural outlier. The site is at 55HCU975628 on the 1:100000 Healesville Mapsheet.

In 1977 a bulldozer was hired by local residents to make an access track along a ridge approximately 1 km north-east of McMahons Creek and through otherwise undisturbed forest typical of the region (*Eucalyptus obliqua*/*Eucalyptus radiata*↔*dives*/scattered *Eucalyptus sieberi*, above shrubs including *Acacia mucronata*, *Banksia spinulosa*, *Hakea decurrens*, *Kunzea ericoides* and *Leptospermum continentale*; nomenclature follows Walsh and Entwisle 1996). The bulldozer had been most recently used in fire prevention works near Bruthen in East Gippsland and was brought to the Upper Yarra Valley on the tray of a large lorry.

In the first year after the track was constructed an unusual wattle was noted growing in the disturbed earth adjacent to the track. That single shrub turned out to be an *Acacia obtusifolia* (Figs 1 and 2). In subsequent years it grew to approximately 3-4 m tall, flowered and set seed. Despite annual searches over the next 4 to 5 years, no other *A. obtusifolia* was found anywhere in the

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Fig. 1. *Acacia obtusifolia* at McMahons Creek, February 2001.

Fig. 2. A closer view of *Acacia obtusifolia* at McMahons Creek.

region (the seed that had been dropped from this one specimen did not germinate and establish in those first few years).

The ridge, including this one wattle shrub (by now a small tree), was burnt in the Ash Wednesday fires of March 1983. The fire was of very high intensity (no nearby unburnt refuges and all above-ground vegetation burnt). However, in the following years regeneration was prolific and some formerly less common shrubs increased in abundance (notably *B. spinulosa* and *E. sieberi*). The single *A. obtusifolia* present before the fire was killed, but a few seedlings established nearby after the fire.

In February 2001 the site was revisited. There were now 14 *A. obtusifolia* individuals, all growing within 4 m of the original (now dead) plant. The tallest was over 4 m tall and most of them had flowered. A few retained healthy seed in pods from the previous season (seed viability was not tested). There were many *Acacia* seeds in the soil around this small stand of *A. obtusifolia*. As *A. mucronata* was also common at the site, it is not known what proportion of these seeds were *A. obtusifolia*. The next fire may lead to a dramatic increase in both the number of *A. obtusifolia* plants and their local distribution.

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The Discovery of Leadbeater's Possum *Gymnobelideus leadbeateri* along the Woori Yallock Creek, Yellingbo

Dan Harley[1]

Abstract
A single Leadbeater's Possum *Gymnobelideus leadbeateri* was discovered denning in a nest box situated along the Woori Yallock Creek, Yellingbo Nature Conservation Reserve. This is the first record of the species from this section of the Reserve, which is more than a kilometre from other sites at which the possum occurs at Yellingbo. It is likely that the individual dispersed from the Cockatoo Creek across unfavourable habitat. (*The Victorian Naturalist* **119** (5), 2002, 233-235)

In 1986, a small, outlying population of the endangered Leadbeater's Possum *Gymnobelideus leadbeateri* was discovered inhabiting lowland swamp forest at Yellingbo Nature Conservation Reserve (Smales 1994). Significantly, it is the only known extant lowland population, although there are historical records of the species in similar habitats from low elevations in south-west Gippsland (McCoy 1867; Brazenor 1932, 1946).

Yellingbo is located approximately 50 km east of Melbourne (37° 47' S, 145° 32' E). The reserve encompasses 591 ha of remnant riparian forest and comprises three separate sections that span stretches of four watercourses, the Woori Yallock, Sheepstation, Cockatoo and Macclesfield Creeks. The nearest records of Leadbeater's Possum to Yellingbo are from Ben Cairn, approximately 17 km to the north-east (Owen 1963; Lindenmayer *et al.* 1989), and Mt Beenak, approximately 18 km to the east (Loyn and McNabb 1982). Mountain Ash *Eucalyptus regnans* forest, typical of that inhabited by the species throughout its core range in the Victorian Central Highlands, occurs at both of these sites.

Since the rediscovery of Leadbeater's Possum in 1961 (Wilkinson 1961), most records have come from montane ash forest above 600 m ASL. (Lindenmayer *et al.* 1991). Yellingbo is situated at 120 m ASL. The sites inhabited by the species at Yellingbo are dominated by Mountain Swamp Gum *Eucalyptus camphora* with a dense middlestorey in places, comprising Woolly Tea-tree *Leptospermum lanigerum*, Prickly Tea-tree *L. juniperinum* or Scented Paperbark *Melaleuca squarrosa* (Harley unpubl. data). Connecting vegetation in either the canopy or middlestorey is an important attribute of Leadbeater's Possum habitat, as the species rarely descends to the ground (Harley unpubl. data). Notably, acacias such as Silver Wattle *Acacia dealbata*, a key food source for the possum in montane ash forest (Smith 1984), are absent from the sites utilised by Leadbeater's Possum for foraging at Yellingbo (Harley unpubl. data).

In order to study the ecology of Leadbeater's Possum in lowland swamp forest, 150 nest boxes were installed at Yellingbo between 1995 and 2000. Coupled with the results of stagwatching surveys, the nest box results suggested that the Yellingbo population of Leadbeater's Possum is restricted to a single section of the reserve along the Cockatoo and Macclesfield Creeks (Harley unpubl. data). The possum's distribution there extends over a long, narrow corridor of forest, approximately 6 km long and typically less than 200 m wide. In contrast, Lindenmayer *et al.* (1993) detected the species at only one of 49 linear corridors surveyed in montane ash forest. Many of these sites contained habitat considered to be suitable for the species, leading the authors to conclude that the possum does not utilise linear corridors of forest in montane ash forest.

As part of the survey to establish the distribution of Leadbeater's Possum at Yellingbo, five nest boxes were installed along the Woori Yallock Creek in February 1999. They were positioned on eucalypts at a height of 3.5 m, with a south-easterly aspect. Each nest box had internal dimensions of 236 × 195 × 356 mm, 19 mm thick walls and an entrance hole of 50 mm diameter. They were locat-

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ed at sites with habitat most resembling that occupied by Leadbeater's Possum along the Cockatoo and Macclesfield Creeks (e.g. presence of *E. camphora* with a tea-tree middlestorey). The five nest boxes were inspected in November 1999, eight months after installation, at which time there was no sign of use by Leadbeater's Possum.

During the course of monitoring the Yellingbo nest boxes in April 2001, a single Leadbeater's Possum was found denning in one of the nest boxes located along the Woori Yallock Creek. This is the first record of the species along this creek. The animal was an adult male weighing 121 g and it had built a nest of shredded bark inside the nest box. It is unclear how long the individual had been resident at the site. No evidence of the species (e.g. nesting material) was found in the other four nest boxes positioned along the Woori Yallock Creek, all of which occur to the north of where the possum was discovered.

On 29 December 2001, one hour after dusk, the individual was observed approximately 30 m north of the nest box in which it was first discovered, eight months earlier. It was detected through imitation of Leadbeater's Possum calls and approached to within one metre. This observation indicates that the individual was still resident at the site, presumably having established its territory in the immediate area.

The riparian forest along the Woori Yallock Creek is dominated by Manna Gum *E. viminalis*, with an understorey of Blackwood *A. melanoxylon* and pockets of Prickly Tea-tree. Much of the forest is quite open in structure. However, there are a number of small, swampy areas along the creek, where the vegetation more closely resembles that found along the Cockatoo and Macclesfield Creeks. The habitat at the site where the possum was discovered is such an area. The canopy is dominated by Mountain Swamp Gum with an understorey of Woolly Tea-tree.

More than a kilometre of partially cleared farmland separates the Cockatoo and Macclesfield Creeks from the site where the possum was discovered on the Woori Yallock Creek. The habitat that remains between the two sites is not suitable for the species, as it consists of a ridge dominated by Messmate *E. obliqua*, and is open in structure. It is very different to the floodplain forest inhabited by Leadbeater's Possum along the Cockatoo and Macclesfield Creeks.

Two likely scenarios could explain the origin of the animal found on the Woori Yallock Creek. Either it had dispersed from Cockatoo Creek or a small, remnant population of Leadbeater's Possum exists along the Woori Yallock Creek. The dispersal scenario would require the possum to have travelled more than 1100 m through partially cleared farmland. While seven dispersal events of this magnitude (i.e. 870-1120 m) have been detected at Yellingbo, the average dispersal distances for Leadbeater's Possums through favourable habitat along the Cockatoo and Macclesfield Creeks are 480 m for males and 450 m for females (Harley unpubl. data).

At sites with few tree hollows, nest boxes can be a valuable survey technique for cryptic, arboreal mammals (Traill and Coates 1993; Soderquist *et al.* 1996; Ward 2000). The discovery of a Leadbeater's Possum along the Woori Yallock Creek highlights their value as a long-term survey technique. One of the main benefits of nest boxes is that they can be left on site for extended periods of time, in marked contrast to the short duration of trapping surveys. They are particularly valuable in surveying for Leadbeater's Possums, because the species' presence in an area can be established from the possums' distinctive nesting material, with no necessity for the animals to be denning in the nest box on the day of inspection.

Between 1995 and 2001, twenty-seven different Leadbeater's Possum colonies deposited nesting material in 111 of the 131 nest boxes (85%) installed along the Cockatoo and Macclesfield Creeks (Harley unpubl. data). This result suggests that, at Yellingbo, if Leadbeater's Possums are resident at a site, there is a strong likelihood that they will deposit nesting material in nest boxes located within their territory. Thus, the absence of nesting material from the four northernmost nest boxes, located along the Woori Yallock Creek, suggests that the species probably does not occur in this part of the reserve. However, it is possible that more individuals occur in the

immediate vicinity of the southernmost nest box that contained the possum, as an area of suitable habitat occurs here on private property adjacent to the reserve. Further surveys will be conducted along the Woori Yallock Creek to determine which of the two possible scenarios is correct.

Acknowledgements
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Ooline *Cadellia pentastylis* F.Muell.: a Survivor

Ron Fletcher[1]

Some plants lead adventurous lives. They manage to survive flood, fire, famine and even the attentions of the taxonomists. A chance meeting with one such was recently made in the small Tregole National Park, a few kilometres south of Morven on the Warrego Highway in south-central Queensland.

Cadellia pentastylis is a large, attractive tree, variously described as 15-22 m tall with some as little as 5 m and the tallest at 28 m, with grey bark described as fissured or tesselated (Figs. 1 and 2) . It apparently flowers only spasmodically and little is known about the viability of the seed. Reproduction is often achieved by suckering, regrowth from rootstock or coppice growth from stumps. The populations are widely scattered through northern New South Wales and south-central Queensland, and the species is registered on the rare or threatened Australian plant list. Some existing stands are on private property where cooperation is sought in preserving populations but where there is pressure from clearing and grazing. Others are more secure in reservations in both New South Wales and Queensland (Benson 1993).

Cadellia pentastylis is typical of relict populations of several species of plants such as *Nothofagus, Livistonia, Casuarina,*

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Fig. 1. Ooline *Cadellia pentastylis*, Tregole National Park, July 2001.

Fig. 2. Foliage of Ooline *Cadellia pentastylis*, Tregole National Park, July 2001.

Acacia and so on, which are scattered throughout Australia, and many of them are survivors from warmer and wetter times when rainforest covered much more of our continent. In some cases they have found niches that have some resemblance to earlier conditions and in others they have modified their habits to keep up with changing climatic conditions (White 1994). *Cadellia pentastylis* would appear to be one of the latter and survives in what has been described with the curious term 'semi-arid rainforest'.

Taxonomically, it has survived several changes, being first described by Ferdinand von Mueller in 1860 from a specimen collected near Tenterfield in Northern New South Wales (APNI), and placed in the family Malpighiaceae. Later, Jadin (1901) included *C. pentastylis* in the Simaroubaceae along with *C. monostylis*. Engler (1931) split *Guilfoylia monostylis* from *Cadellia* and established the monotypic genera *Cadellia, Suriana* and *Guilfoylia*. Cronquist (1981) placed *Cadellia, Suriana, Guilfoylia* and *Stylobasium* in a new family, the Surianaceae, and this is the classification followed in the *Flora of Australia* (Benson). The monotypic genus *Cadellia* takes its name from Francis Cadell, a pioneer river-boat captain on the Murray-Darling system during the late 1850s. His shipping company was responsible for the transport of about 16,000 specimens, botanical and zoological, from Mildura to Adelaide in 1858, from where they were sent on to Melbourne. Mueller had of course been actively interested in the exploration of the Murray-Darling Basin and visited the area in 1853-54, soliciting assistance and making extensive collections which resulted in many specimens being shipped from the region in the subsequent decade (Orchard 1997).

Acknowledgements

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Foraminifera from Lake Corangamite, Victoria

Ken N Bell[1]

Abstract

Surface sediment samples collected at Lake Corangamite, Victoria, contained dead specimens of the calcareous foraminiferan *Elphidium excavatum excavatum* (Terquem, 1875). (*The Victorian Naturalist* **119** (5), 2002, 237)

Foraminiferans are usually restricted to fully marine or marine brackish waters. They have been recorded from non-marine saline waters in many parts of the world (Resig 1974, and references therein). In Victoria, specimens of an unidentified, living foraminiferan were reported from a salt lake near Douglas, Western Victoria (Parr 1942) and two agglutinated species (*Trochamminita irregularis* Cushman and Bronnimann, *Miliammina fusca* (Brady)) have been found in freshwater (Bell 1983). Cann and DeDeckker (1981) reported a fauna of two species (*Elphidium* sp., *Trochammina* sp.) from the Coorong, South Australia.

Lake Corangamite, which lies to the west of Colac, is the largest natural lake in Victoria. It is about 32 km long and ranges in width from 2 to 11 km, giving a total area of about 250 km^2. In recent geological times the lake was much larger, having an area of perhaps 1700 km^2 and being markedly deeper (Currey 1964). The lake is shallow, although this, of course, varies with seasonal changes; Skeats and James (1937) give the depth as less than 1.5 m whilst Bayly and Williams (1973) give the maximum depth during the great floods of 1953 as 3.4 m. Because Lake Corangamite is a basin of internal drainage its salinity can be high, but it shows significant fluctuations with values of three times seawater (Skeats and James 1937) to 12.5 ppt in 1953 and 6.5 ppt in 1960 (Bayly and Williams 1973).

The samples which contained the foraminiferans were collected (May 2001) on the northwest side of the lake near Foxhow. The calcareous benthic species *Elphidium excavatum excavatum* (Terquem) was present. No specimens were alive when collected and none had traces of protoplasm present. Specimens were well preserved with only slight surface frosting in a few cases and were present in infrequent numbers, about 10 per 200 g of sediment. This species is usually restricted to brackish or marginal marine environments such as estuaries or brackish lagoons. There seems little possibility of the specimens being eroded from geological sediments; the COLAC Geological Map (1973) shows no Tertiary sediments outcropping around the lake edges (although Skeats and James (1937) mention that such outcrops do occasionally occur, they give no locations), and the Pliocene Moorabool Viaduct Sands, which underlie the recent soils and lunettes in the area, consist of non-marine sands and gravels. The only recorded fossil occurrences of this taxon are two records in the New Zealand Pliocene (Hayward *et al.* 1997). One would also expect more species to be present if the specimens were geologically derived. Whether or not these specimens represent a living population of foraminiferans in Lake Corangamite or are representatives of a transient, introduced population will require more study.

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Winter Keeps Us Warm

The lines from *The Waste Land* by TS Eliot,

> 'Winter kept us warm, covering
> Earth in forgetful snow...'

have always appealed to me for a couple of reasons. Apart from my enjoyment of the apparent incongruity, they have so much additional meaning to an alpine ecologist.

The natural assumption about mountain environments is that they are especially harsh on animals, particularly in winter. This is more true of countries such as Australia where the fauna occupying the mountains are not pre-adapted to the environment by reason of living at high latitude (with the attendant benefit of experiencing harsh conditions at lower altitude).

Fig. 1. *Antechinus swainsonii* Dusky Antechinus

However, one species gives us a good clue as to when the weather is most harsh. The Dusky Antechinus *Antechinus swainsonii* (Fig. 1), along with others of its genus, is well known for the male die-off immediately after breeding. Yet looking at my records gathered over the years in the mountains, and at what foxes pick up in their foraging, autumn seems by far the most dangerous time. Spring has its male die-off admittedly, and winter is a time when you would expect an insectivorous mammal in the snow to do it tough, but all is not quiescent beneath the snow (see Green 1997 for what goes on with insects beneath the snow).

I was doing a small mammal radio tracking project some years ago, looking at what changes in home range were caused by snow cover, and I was alarmed at the mortality among my subject animals. This was irrespective of who collared the animals, whether it was I or a more experienced colleague. I looked back on the halcyon days of my PhD to when I had zero mortality in a winter radio tracking program. What I now know is that the big die-off in mountain Dusky Antechinuses is in autumn. I was merely collaring already doomed animals. In a paper published last year (Green 2001), I looked at autumnal reduction in body weight in the Dusky Antechinus. This phenomenon, of a reduction in lean mass rather than a metabolisation of fat reserves (Dehnel's phenomenon), was known previously only from northern hemisphere rodents and insectivores. However, above the snowline in the Snowy Mountains, the average weight of individual Dusky Antechinuses falls by over 12% in the short period from April to May. To go and lose all this body weight put on at so much expense in foraging effort in late summer seemed inexplicable at first – after all, if there was an advantage to being small in winter, why go to so much trouble to get big in summer? The reason for this loss of weight in autumn is not inextricably linked with the availability of food. This is apparent when you look at animals that have lost weight in autumn and revisit the same animals in winter to find that they have put the weight back on again under the cover of snow, despite the fact that there is no increase in the amount of food available.

What is happening is that the animals are undergoing a period of great thermal stress in a harsh microclimate when they are exposed to the frost and cold rain and sleet of autumn but are less stressed in winter when the snow cover keeps them warm. The evidence for this can be seen in the fact that the heavier animals (that lose a bit of weight in autumn) can be found throughout

winter whereas the lighter animals disappear from the population. It is an advantage to be a lightweight under the winter snow (the less you weigh the less you have to eat to keep going and therefore the less you have to expose yourself to the elements by foraging) whereas in autumn it pays to be a heavyweight so that you have something in reserve. This autumnal thermal stress was what was killing my animals. Foxes benefit from this. You would expect that consumption of antechinuses would peak in spring, with foxes scavenging all the dead males. However, this is not the case. In a study I have just completed (Green in press), remains of antechinuses in scats peaked in autumn at both alpine and subalpine altitudes, in all three years of the study. This high autumnal mortality of small mammals due to severe thermal stress is not confined to Australia but is well known overseas, as are the ameliorating effects of snow cover. Eliot seems to have known it too.

Winter kept us cool? Some species, however, are more in need of keeping cool – 2°C to be exact. This is the preferred winter temperature of the Mountain Pygmy-possum *Burramys parvus*. If the temperature goes above or below this then the shorter bouts of torpor (or rather the longer periods of arousal) increase energetic demands and hence use up valuable fat reserves that have to support the animal through the winter. This is particularly the case when temperatures rise, causing increased body temperature and hence metabolic rate.

Other small mammals in the mountains, whilst not hibernating, do restrict their activity. The Broad-toothed Rat *Mastacomys fuscus* restricts its movements to a minimum in winter and builds large stores of grass to feed on when foraging is restricted. It also builds a large ball nest of grass on the soil surface (but beneath the snow) where it takes advantage of a double layer of insulation (Green 1998). In contrast, the Bush Rat *Rattus fuscipes* tends to dig deeper burrows, and the newly excavated fans of soil coming from a rat hole are a feature of autumn beneath the bushes in the mountains. The Bush Rat and the two species of antechinus are particularly active in winter. The Agile Antechinus *A. agilis*, also active under the snow, is less common above the treeline. It builds a nest in a hollow tree or rock and insulates it with leaves. In one nestbox I placed in a tree for this purpose, I counted over 1000 dry Snowgum leaves that had been carried the three metres or so up the tree trunk from the woodland floor by the resident Agile Antechinuses.

The rest of the animals above the snow (such as ourselves), not kept warm by the snow, just have to rug up for the winter or fluff up like birds (although thornbills and scrubwrens will roost beneath the snow at times). But for the small mammals an early snowfall such as we had this year was a blessing, reducing autumn to a short period and covering Earth in forgetful snow.

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Snow in Spring

In the short days of winter it is sometimes difficult to find any evidence of animal activity in the Snowgum woodlands, particularly on a windy day when every movement is disguised by blowing snow, flapping bark or falling leaves. The winter just past, with its early, deep snow meant that the few resident birds were easy to see, forced up out of the shrubs as these became buried in the best early snow for some years. One day, I managed to tick off ten species out of the 12 or so I could have hoped to record, by sight, sound or other evidence. But even on that day the woodlands seemed quiet. Come spring, even with snow on the ground, the Snowgum woodlands come alive with birds, particularly once the Royal Grevillea *Grevillea victoriae* comes into flower. It is quite interesting to follow the regular pattern of bird arrivals in this spring migration.

Everything is not fixed in time though, and the timing, if not the pattern of arrivals, has changed over the years. There has been about a 30% reduction in snow cover in the Snowy Mountains over the past 45 years. This has led to interesting responses from the birds migrating back to the mountains. There is a pattern of earlier arrival in the 1980s and/or 1990s compared to the 1970s. For 11 bird species for which there are sufficient data, the earliest record for nine of them was in the 1990s and the 1980s (the latter generally differing by only a few days from the earliest date for the 1990s) with the time of influx into the mountains sometimes more than a month earlier than in the 1970s.

Interestingly, two species showed virtually no change in arrival date across the three decades. The Grey Fantail *Rhipidura fuliginosa* is probably constrained by the need for flying insects and Silvereyes *Zosterops lateralis* – well, who knows what local migration cues they follow? In some earlier work that I did with Will Osborne, we looked at the cues that brought in the birds. The birds that we recorded as arriving earlier included honeyeaters that depend on the flowering of shrubs which pop out from under the snow, and birds that are largely dependent upon snow-free ground for foraging such as Australian Kestrel *Falco cenchroides*, Flame Robin *Petroica phoenicea* and the Australian Pipit *Anthus australis*. We built up that work from years of accumulated records, but to look more closely at the impacts of snow depth, cover, and shrub exposure and flowering I have had to undertake a weekly survey from about mid-August until the last of the stragglers (Grey Fantails) arrive.

It is interesting to make these weekly bird observations and to see these patterns followed year after year. Of course some unexpected effects are unearthed. In spring, Flame Robins forage in the open alpine snowfields (above treeline). This means that for a few weeks the most commonly seen robin on my rounds of the woodlands is the Pink Robin *Petroica rodinogaster* and another common species at this time is the Olive Whistler *Pachycephala olivacea*.

Other movement patterns in the mountains are of interest in spring, including the arrival of insects on the snow. These are not the annual migrants, but insects swept up into the mountains by weather patterns in which they would have been better advised not to fly. Last spring, half an hour after crossing a snow-filled pass on foot, I retraced my steps and counted the insects that had accumulated in my footprints. The insects were rolling and tumbling across the pass at a rate of at least 135 per hour (rolling and tumbling because if they had been airborne they wouldn't have accumulated in my footprints). Some migratory insects do get caught; the Caper White Butterfly *Anaphaeis java* which includes the Snowy Mountains region in its strange southerly looping migratory path is often trapped.

Then, of course, there is the Bogong Moth *Agrotis infusa*. This appears on the snow in spring and is quickly taken up by Little Ravens *Corvus mellori* and Richard's Pipits. I have sometimes wondered where the moths hide during the day whilst waiting for their boulder pile aestivation sites to thaw out. In the classic 1950s work on the species, Ian Common found temporary camps in locations such as under logs in the woodlands surrounding his study site on Mt Gingera (on the ACT/NSW border). That's

all very well, and the moths do a similar thing in woodlands in the Snowy Mountains, but so many of the aestivation sites are well above the treeline, so where are the moths hiding so early? The clue came to me as I sat in my tent while watching ravens forage in the grass and shrubs that were exposed in patches in the snow cover. Despite days of searching for what they were feeding on I could find only a few dead arctiid moth larvae, the spotted grasshoppers *Monistria concinna* which the birds seem to ignore, and ants. It was later while catching Bogong Moths on a cold night for studies on arsenic transport that I got confirmation of my guess. I released the moths that were excess to my needs onto the grass; they disappeared and within seconds I could find none. Of course, being grown-up cutworms they are probably used to hiding in grass, but I was amazed at how quickly and completely they were hidden from my searching fingers – but obviously not from the raven beaks!

All through spring time the snow is slowly retreating. One thing slower to retreat is the ice on Blue Lake, the largest and deepest of the mainland glacial lakes. The ice gets to quite a reasonable thickness; I had to drill 1.4 metres to get through one September. Eventually, with the warmer weather and the pressure of incoming water from the thawing snow, the ice cover breaks up and the floating bits wash away or slowly melt. In 1970 and 1971 the ice didn't break up until late November and there was still ice on the lake in December, whereas in 1999 it was all gone by early October.

Last spring, I was on the middle of Blue Lake on 23 October and the ice was still a good 50 cm thick. In places there were patches of pink – snow algae. I didn't think much more about it until I was in the car on my way home. Then I recollected that Harvey Marchant's work on snow algae stated that the spores came from the soil and moved up into the snowpack once there was free liquid water, returning to the soil as soon as the snow melted. So how did they get to the middle of the lake? I rang Harvey. Snow algae hadn't been recorded on Australian lake ice before – could I get a sample? The next day was thundery so I gave it a miss and went back on the 25th. The lake was now either open water or watery-looking ice too thin to support me. Only about 20% of the lake could support a person on skis – this just two days after I had lunched in the middle! I was able to get out 60 m to get a sample, but it was useless for identification. Still, maybe this month ...?

Reading list

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Note: The trips to Blue Lake referred to above are to build up a data base of ice breakup over time as a means of monitoring regional evidence of global warming. I am interested in obtaining photographs or recollections of when ice breakup occurred in the past. A photograph of the lake with full ice on it is of no use (unless it is very late in the spring/summer), nor is a photograph of open water (unless it is very early in the spring). However, if anyone has photos of Blue Lake (with year and month recorded) with ice already breaking up then I will be able to add another year to the list. I am particularly interested in 1982 (the cold year when there was not much snow) and anything pre-1970. Therefore if you, or anyone you know, has relevant dated photos I would be delighted to hear from you. I can be contacted at the address below.

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William Nigel Balcombe Quick

6 June 1928 – 4 April 2002

Nigel Quick (often known as 'Nige') was born in Melbourne and grew up in the inner suburb of Toorak. He was the only child of Hilary and William Balcombe Quick, an honorary surgeon and head of the Alfred Hospital Board at Melbourne. Nige was the great great grandson of Lieutenant Colonel William Balcombe, Napoleon's jailer on the small oceanic island of St Helena in the southern Atlantic, and East India Company Representative charged with provisioning the Company's ships.

Nige was educated at Melbourne Grammar School from 1938 until 1946 and it was during this time that his interest in entomology began. He made contact with Alex Burns, curator of Entomology at the National Museum of Victoria, and through this association met other keen 'youngsters' and experienced amateurs who provided encouragement, guidance and local knowledge of the fauna of the Melbourne environment.

Nige went on to study science at Melbourne University but never completed his degree, instead taking employment at the engineering firm McPhersons where over an eight year period he acquired exceptional knowledge of tools and their practical use.

During this period Nige, often accompanied by Charles McCubbin, travelled far and wide throughout the State to collect butterflies and other insects, fish and plants, making trips to the poorly surveyed areas of the north-west (Big and Little Deserts) and far east (East Gippsland).

Around 1956, Nige left McPhersons and started his own business, setting up a plant nursery, 'Dargon Hill', which he established on an elevated site on the edge of the suburb of Glen Waverley. The nursery specialised in native plants, all of which Nige grew from seed and cuttings collected on field trips. Most of the plant material came from Victoria but he made an extended trip to WA specifically to collect samples of the rich endemic flora. Nige was a pioneer in the propagation and selling of native plants.

In 1960, he married Gwenda Gerraty. They had two children, David and Lucinda. During the 1970s the family opened a shop called 'Gem Minerals in Syndal'. The business reflected a long interest Nige had developed in gemstones and minerals over the years while collecting plant seed.

Nige joined the Entomological Society of Victoria when it was reformed in 1961, and was Vice-President from 1973 to 1976. In 1971 he began writing articles for the *Victorian Entomologist*, the Society's journal. Over the ensuing 28 years he contributed 51 articles. He also published three papers in *The Victorian Naturalist, Queensland Naturalist* and *Australian Journal of Entomology*. His most productive period was during the early and mid-1970s when he handled the publication of the journal and was assistant editor for several issues. Most publications dealt with the natural history of butterflies, novel methods of setting, preserving and rearing specimens, and technical aspects of the ENTRECS scheme, a computerised distribution database that he pioneered in the

Nigel Quick at Garfield North in the late 1990s.

mid-1970s (well before most people had even heard of computers!). However, he also wrote on a range of other topics, including species protection and conservation, book reviews and field trip reports.

In 1979, he was made an Honorary member of the Entomological Society of Victoria in recognition of his pioneering work on the ENTRECS scheme. However, he subsequently resigned from the Society, mainly because of poor health, and contributed very few articles after 1985.

In 1980, Nige and Gwen lived at Kuranda near Cairns where Nige studied the local butterflies, plants and wildlife before returning to Victoria in 1983.

Nige served on the advisory committee of the Melbourne Zoo butterfly house in 1984, and provided advice on suitable species, breeding requirements, and the conditions needed to sustain tropical insect populations. In 1987, 4023 specimens of Australian butterflies from Nigel's private collection were incorporated with the DF Crosby collection and donated to the Australian National Insect Collection. This collection includes much important historical material from areas where populations of many species are no longer extant, especially in Victoria.

Nige had a very wide interest in natural history, including botany, geology, ornithology and the ecological associations between animals and plants. During the early years he became an expert on Victorian native freshwater fish, and collected many species throughout the State. However, entomology, particularly butterflies, remained a major preoccupation throughout his life. Nige made a significant contribution to entomology in Australia and was widely known and respected by professional entomologists. He corresponded frequently with other entomologists, assisted colleagues, students and newcomers to the field, and was very generous and helpful in passing on his knowledge, particularly in his later years. He thought deeply about his subject and was never short of scientific ideas to explain natural phenomena. Nige was an exceptionally gifted naturalist and a perfectionist in all aspects, from making careful field observations, rearing the early stages, to preparing specimens for the collection, which he did with meticulous precision. He was a proficient photographer and had expert working knowledge of cameras and their lenses. But he was also an excellent draughtsman and a competent wildlife artist. He painted quite a few transparent watercolour paintings of insects, and also some landscapes in oil.

His current private collection, comprising about 40 cabinet drawers and 15 storeboxes (representing a diverse array of temperate and tropical butterflies, macro moths, cicadas and jewel beetles), along with his vast personal photographic library, has kindly been donated by Nigel's descendants to the Australian National Insect Collection where research workers will have ready access to study his material.

Nige was courteous, respectful and eloquent with a witty sense of humour. He was a thorough gentleman, although at times temperamental. He died quite suddenly at the age of 73 soon after being diagnosed with cancer. A funeral service was held on 12 April 2002 at the St Andrews Uniting Church in Bunyip, followed by a graveside commital in the Bunyip Cemetary.

Those of us who knew or were close to Nige were the beneficiaries of his enormous talent and intellect. He was the last of the older generation of lepidopterists in Victoria still active in the field. Nige will be greatly missed in the future, but his contribution to entomology will live on for a very long time.

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Butterflies of Australia: their Identification, Biology and Distribution

by Michael F Braby

Publisher: *CSIRO Publishing, Collingwood, 2000. 1008 pp, 2 hardback volumes, 70 colour plates. ISBN 0643065911. RRP $195*

For centuries enthusiasts have found Lepidoptera to be popular and accessible insects for study. Butterflies in particular depict, with their irresistible, exquisite wing patterns and complex life histories, an interesting subject of beauty and curiosity. They are also of scientific importance, being excellent indicator species of biodiversity and useful for genetic research or studies in ecology and evolution.

Butterflies of Australia by Michael Braby has followed the similarly titled classic publications by IFB Common and DF Waterhouse (1972 to 1981). Two volumes of this latest work represent an indication of the massive increase in information that has occurred in the last twenty years. Braby acknowledges that much of this new data has been provided by amateur researchers.

Volume One begins with an introduction to the history, classification, morphology and distribution of Australian butterflies and also includes an important section on their conservation. Then follows a chapter (mostly for amateurs) on the collection, preservation and study of these insects. Following a checklist of species and subspecies recorded from the Australian region, the species accounts begin. These include three families; Hesperiidae (Skippers), Papilionidae (Swallowtails) and Peridae (Whites and Yellows). Then follows colour plates (with label data) of all species (400 plus) and many subspecies found in the Australian faunal region and peripheral political boundaries. Volume One concludes with a selection of field photographs of adult and juvenile butterflies.

Volume Two has species accounts of the remaining two families; Nymphalidae (Browns, Nymphs and Danaines) and Lycaenidae (Blues, Coppers, Hairstreaks and Metalmarks). The volume is completed with a series of appendices including lists of larval food plants, attendant ants and a useful glossary. A comprehensive list of references is given only in the second volume.

All chapters are evenly presented with accurate information included (where known) for all families, subfamilies, genera and species. The systematic placement of most genera is well researched and the description of each species and genus is generally accurate. A distribution map is given for each species, and includes boundaries delimiting the subspecies.

Some important additions have been made since the publications of Common and Waterhouse. These include the use of new common and recently established or corrected scientific names and up-to-date informative data on butterfly life histories, behaviour and distribution. Each species' text is accompanied by black and white photos with bar indicators emphasising specific points of identification.

Significantly, several subspecies have been 'sunk'. With such an action, which may or may not be productive, an illustration of specimens (or similar specimens) from the type locality is essential. This has not been done for species such as *Trapezites lutea* in Volume One and may be misleading. Similar difficulties may occur for overseas readers, for instance, where an Australian representative species, that may have numerous subspecies in South East Asian or Pacific Islands, cannot be identified at the subspecific level in the text until the distribution and habitat section is scrutinised. This is somewhat rectified by including the Australian subspecies in the checklist in Volume One. Inevitably, in such a large two-volume publication, referral between the volumes can be cumbersome.

Amateur enthusiasts would probably have expected more coloured figures of aberrations, forms and subspecies. There is certainly room on some coloured plates for this. It appears to be an oversight that the

distinctive female of that great Australian icon, the 'Ulysses Swallowtail' is omitted, wheras the equally spectacular two species of Birdwing are well accommodated, sharing two plates. The species in some colour plates (e.g. 25 and 34) are reduced a little too far for accurate identification.

These inconsistencies do not detract from the value of the publication. There are few typographical errors and the text information and photographic presentation is of a high standard. Michael Braby has produced a masterful work, which in this world of information and technology, sets the standard for all other proposed publications on the butterfly fauna of this planet. The excellent quality is seen foremost as a reflection of the abilities and perseverance of the author. There are also other fine technical contributions made by ED Edwards, MS Upton and Professor JFR Kerr.

Butterflies of Australia recently (and deservedly) won the prestigious 2001 Whitley Medal. It is a publication worthy of the bookshelves of all naturalists, butterfly enthusiasts and researchers. It is to be hoped that a smaller 'glove-box' edition will follow.

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Dragonflies of the World

by Jill Silsby

Publisher: *CSIRO Publishing, 2001. Hardback, 224 pages, colour illustrations. ISBN 0643065121. $59.95*

This book is an excellent introduction to the dragonfly fauna of the world and will be a valuable addition to the odonate literature. This wonderfully presented colour book will interest amateur collectors through to the professional odonatologists. The author has written the book in a relaxed, easily understood, semi-technical style that makes it a delight to read. The book contains superb colour photographs of over 300 dragonfly species, some as larvae, and many of their habitats. It is testament to the 20 years of hard work by the author photographing and studying dragonflies in many countries.

The layout and production is very pleasing, with colour photographs on almost every page. However, it is not just a colour book, as the chapters provide a wealth of general information on dragonflies, ranging from evolution to ecology, to conservation. The science is strengthened by having many leading odonatologists write or collaborate on many chapters. The book is well structured, with 12 chapters, 11 short, covering the Introduction, Today's Odonata, Life Cycle, The Perfect Hunting Machine, Lords of the Air, Colour Polymorphism, Territory and Reproduction, Habitat and Refugia, Evolutionary Riddles, Artificial Rearing, and Conservation, and a large chapter of 114 pages on Odonata Around the World. This large chapter is the backbone of the book and is where the reader is provided with an overview of the world's dragonfly fauna to the subfamily level. A general overview of each subfamily is given, as well as the ecology of the most distinctive and interesting representatives.

The book also includes a very informative glossary, which will be valuable for readers unfamiliar with dragonfly terminology. At the back is included a list of the World Dragonfly Societies, a helpful list of the bibliographies used, and indexes to both the species and to general terms.

Australian odonatologists will find the many excellent photographs of 36 species found in Australia very useful. The choice of a large photograph of the dazzling *Rhyothemis graphiptera* on the front cover also highlights the beauty of Australia's dragonflies. The Australian fauna is well detailed and with the many photographs provides the reader with a good insight into the diversity of the Australian species.

There are a few minor errors, which is understandable when trying to cover such a large fauna. The distribution information of the caption 'Tasmania's very rare *Ictinogomphus dobsoni* Dobson's Tiger wingspan 75 mm' (the lower photograph on page 140), is incorrect, as *I. dobsoni* only occurs in the north-west of Western Australia (Watson *et al.* 1991). The central photograph on page 153 (identified as a male *Eusynthemis nigra*) is a male *Hemicordulia australiae*. The third sentence of the first paragraph on page 190 states that 'A second is to break up the small family Neopetaliidae, with one species to remain in Aeshnoidea while seven are transferred to Libelluloidea' is incorrect. It should read that one species remains in the family Neopetaliidae, which is moved to the Libelluloidea, while the remaining eight species are placed in the family Austropetaliidae and remain in Aeshnoidea (Carle and Louton 1994, Carle 1995). Also on page 190, paragraph four heavily criticises the classification system of only Bechly and not other phylogeneticists, which is unnecessary, as the jury is still out in the classification case.

I would recommend this wonderful colour book as a 'must buy' for all people interested in dragonflies.

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Possums: The Brushtails, Ringtails and Greater Glider

by Anne Kerle

Publisher: *University of New South Wales Press 2001. 128 pp.*
ISBN 0868404195. RRP $39.95

This is the twelfth book in the Australian Natural History Series, a series to be commended for bringing well-written species accounts to the general public. For the past few decades, natural history writing for the general audience has consisted of books for identification of the various taxa, with the occasional travelogue through the natural history world, or books focussed on particular regions. The Australian Natural History Series from the University of New South Wales Press was a natural, and most welcome, extension of this. With this series the facts about a species or group of related species are available to those with limited access to the scientific literature. Unlike some single-author views of a species, where the veracity of an opinion cannot be checked, this series employs the scientific tradition of acknowledging the sources of the information, albeit in a more reader-friendly way than the usual scientific notation. This makes the series useful to the professional as well as to the casual reader.

The latest offering is from Anne Kerle who grew up geographically and professionally with possums, starting with her honours project on Mountain Pygmy Possums (covered in this series by Ian Mansergh and Linda Broome) before moving on to northern Brushtail Possums for further research. The breadth of knowledge, gained from her own research, from the scientific work of others and from indigenous people, is brought together in this book to give a highly readable and fact-filled account.

The first mainland marsupial to be recognised as a marsupial was not a kangaroo but a possum. Cook and Banks likened the animal they saw to the Brazilian Opossum (the

first marsupial known to European science) and the name stuck - minus the 'O'. Apart from noises on the roof or depredations to fruit and rose bushes what do we know about possums? Who would have thought that the Common Brushtail Possum, so adept at living with humans in our cities and as a pest in New Zealand could be declining here in Australia? It has disappeared from half of its pre-European range. Some of the threats to possums are covered in this book. The fur trade took four million pelts in 1906, but today the threats are more from the usual suspects: habitat clearance and ferals, including one not generally thought of, the honey bee that in one location occupied 25% of hollow trees making them unsuitable for possums.

This book covers the thirteen species of large Australian possums in two families, the Phalangeridae (five species) and the Pseudocheiridae (eight species). Four families are not covered and, apart from one single species treatment already published there is room for another book in this series. This book examines what is a possum and how the group evolved, has general accounts of the thirteen species including distribution, scats, skulls and footprints of the better-known ones, habitat preferences, food, breeding, behaviour and finally their interactions with humans.

I had few quibbles. Figure 1.1 has Vombatidae as a suborder (rather than Vombatiformes) thus on p. 16 the Koala (family Phascolarctidae) is included in the Vombatidae (the wombats). On p. 19 the flying term 'attitude' (meaning the angle of its axes relative to the airflow) has morphed into altitude (height above sea level). Additionally (a quibble from a mountain ecologist and a lapse in an author who has studied the Mountain Pygmy Possum) on p. 52 Common Brushtail Possums have been found 'in sub-alpine woodlands and above the snowline' (as if sub-alpine woodlands occur anywhere else). I also had trouble working out what were the units on the Y axis in Fig. 5.2.

There has been some debate in wildlife circles about immunocontraception to control reproduction in pest animals. This is a potential pathway in Australia to reduce numbers of foxes (a long way from where there are native populations of this species). The possibility of this technique becoming widespread in New Zealand to control possums (relatively close to source native populations) may well widen the debate.

In all, the book was informative and enjoyable to read and I for one will be dipping into it to learn more about the animals that manage to raid my grape vine the night before the grapes are ready for picking.

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One Hundred Years Ago

Notes on a Rare Victorian Shark

By Jas. A. Kershaw, F.E.S., Curator of the Zoological Dept., National Museum
(*Read before the Field Naturalists' Club of Victoria*, 14*th July*, 1902.)

On the 2nd May last a large shark was captured in Hobson's Bay, off Williamstown, which was quite unknown to any of the fishermen and others who saw it. It was captured through becoming entangled in the nets of some local fishermen, which it damaged considerably, and unfortunately bruised itself a good deal in its powerful struggles to escape.

Its captors immediately disembowled it, and had it conveyed to the city for exhibition purposes, where it was secured for the Museum.

It proved to be a medium-sized male specimen of the Basking Shark, *Cetorhinus maximus*, Gunner, and measured a total length of 12 feet 11 inches.

The only previous record of its occurrence in Victorian waters is that given by Sir Frederick M'Coy in the Prodromus Zoology Victoria, vol. ii, where he describes and figures a large specimen measuring 31 feet 6 inches, which was captured in the fishermen's nets at Portland in November 1883. This specimen was exhibited in the city for some days, but, being hot weather, it was rendered useless for museum purposes.

From *The Victorian Naturalist* **XIX**, p 62, August 7, 1902

The Field Naturalists Club of Victoria Inc.

Reg No A0033611X

Established 1880

In which is incorporated the Microscopical Society of Victoria

OBJECTIVES: ***To stimulate interest in natural history and to preserve and protect Australian flora and fauna.***

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From the Editors

Authors are asked to carefully read the guidelines and consult the most recent issue of the journal when preparing a manuscript for publication.

The Victorian Naturalist would not be successful without the enormous amount of time and effort given voluntarily by a large number of people who work behind the scenes.

One of the most important editorial tasks is to have papers refereed. The Editors would like to say thank you to those people who refereed manuscripts published during 2002:

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Dave Britton
Rhonda Butcher
Malcolm Calder
Rohan Clarke
John Dean
Kelvyn Dunn
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The Victorian Naturalist publishes articles for a wide and varied audience. We have a team of dedicated proof-readers who help with the readability and expression of our articles.

Ken Bell
Andrew Bennett
Arnis Dzedins
Ian Endersby
Maria Gibson
Ken Green
Pat Grey
Murray Haby
Virgil Hubregtse
Michael McBain
Tom May
Ian Mansergh
Geoffrey Paterson
John Seebeck
Rob Wallis
Gretna Weste
Jenny Wilson
Alan Yen

Sincere thanks to our book reviewers for 2002 who provided interesting and insightful comments on a wide range of books and other materials:

Andrew Atkins
Margaret Corrick
Stuart Dashper
Gwen Elliot
Rodger Elliot
Cecily Falkingham
Ken Green
John Hawking
Simon Lewis
Angus Martin
Sara Maroske
Tim New
Cheryl O'Dwyer
Gary Presland
Gerry Quinn
Melody Serena
Jenny Tonkin

As always we particularly thank our authors who provide us with excellent material for publication.

Special thanks to Ken Green for his 'Naturalist in the Mountains' series to commemorate The United Nations International Year of Mountains 2002.

Our editorial advisory team continues to provide valuable advice and assistance: Ian Endersby, Ian Mansergh, Tom May, and John Seebeck.

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Editors: Alistair Evans and Anne Morton

Research Reports

A Population Study of Eastern Grey Kangaroos *Macropus giganteus* at Tower Hill State Game Reserve, South-western Victoria, *by Eve McDonald-Madden and Graeme Coulson* 252

Potential Dispersal Agents of Higher Plants in the Kosciuszko Alpine Area, *by Karen C Rudkin and Catherine M Pickering* ...258

The Red Fox *Vulpes vulpes* L. in the Dandenong Creek Valley: Impacts on Wildlife and an Integrated Program for their Control, *by A Morton, D Tagg, R Wallis and J White* 269

Naturalist in the Mountains

Flying Spiders and Crawling Flies, *by Ken Green* 276

Book Reviews

Grassed Up: Guidelines for Revegetating with Australian Native Grasses, *by Cathy Waters, Wal Whalley and Charles Huxtable, reviewed by Cheryl O'Dwyer* 278

Platypus: the Extraordinary Story of How a Curious Creature Baffled the World, *by Ann Moyal, reviewed by Melody Serena*.279

Working on Country: Contemporary Indigenous Management of Australia's Land and Coastal Regions, *edited by Richard Baker, Jocelyn Davies and Elspeth Young, reviewed by Gary Presland* 280

Gardening With Australian Rainforest Plants, *by Ralph Bailey and Julie Lake, reviewed by Gwen and Rodger Elliot* 281

Guidelines for Authors at the end of this issue

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Cover: Eastern Grey Kangaroo *Macropus giganteus*. See Research Report on p. 252. Photo by Keith Dempster.

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A Population Study of Eastern Grey Kangaroos *Macropus giganteus* at Tower Hill State Game Reserve, South-western Victoria

Eve McDonald-Madden[1] and Graeme Coulson[1]

Abstract

Overabundance in native species has recently become an important focus for wildlife management. The negative effects of overabundant macropod populations include threats to human life or livelihood, depression of the density of favoured species, decline in body condition and reproduction, and a loss of equilibrium between flora and fauna. This study was undertaken at Tower Hill State Game Reserve in south-western Victoria. The population of Eastern Grey Kangaroos *Macropus giganteus* in the reserve is derived from a number of individuals released in 1964, and this study established that the current population totals about 150 individuals. The adult sex ratio was at parity and 71 % of females in the population were breeding, suggesting that this population has the potential for rapid increase. Further study into the population's growth trajectory and the development of a management plan is needed to avoid problems of over-grazing and over-browsing. (*The Victorian Naturalist* **119** (6), 2002, 252-258)

Introduction

Overabundance in native species has recently become an important focus of wildlife management (Garrott *et al.* 1993; Rodger 1998). In parts of North America, overabundance of ungulates, particularly White-tailed Deer *Odocoileus virginianus* and Elk *Cervus elaphus*, has become a major management issue in national parks and on private land (e.g. Healy *et al.* 1997; McShea and Rappole 1997). Some Australian species seem to be undergoing parallel growth rates to those witnessed in North America. In Australia, the Koala *Phascolarctos cinereus* (Martin and Handasyde 1999) and a number of macropod species have been identified as problematic (Coulson 1998).

Overabundant macropod species have been shown to have a negative effect on agricultural yields (Hill *et al.* 1988) and can also have deleterious effects on biota in areas where grazing pressure is concentrated, such as nature reserves (Neave and Tanton 1989; Coulson 1997). In particular, problems arise in populations that are closed to emigration, either by impenetrable habitat or by fencing. In the past the deliberate introduction of kangaroo populations into closed areas has resulted in problems due to overpopulation (see Coulson *in press*).

This study was undertaken at Tower Hill State Game Reserve, a small reserve of native habitat, isolated from other native vegetation by expanses of cleared pasture. Over the years, macropod species including Eastern Grey Kangaroos *Macropus giganteus*, Black Wallabies *Wallabia bicolor* and Red-necked Wallabies *Macropus rufogriseus* (introduction unsuccessful), have been released into the reserve (Goldstraw 1986). In November 1964, Eastern Grey Kangaroos were reintroduced into the reserve (Goldstraw 1986). They were initially introduced to two enclosures planted with open forest vegetation, designed to acclimatize macropod breeding stock before ultimate release. The initial numbers of kangaroo released seem to be unrecorded; however anecdotal observations of releases and deaths from 1979 to 1985 are available. Records show that 19 kangaroos were released intermittently over six years, with nine of those released animals dying in their enclosures before release into the reserve itself. Records of observations from outside the enclosures over the same period show a maximum number of 36 animals.

Eastern Grey Kangaroos have been shown to inhabit ecotones of ample forest cover and open grassy feeding grounds (Hill 1981; Short and Grigg 1982). Due to

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their need for cover these kangaroos are highly restricted to areas of lateral vegetation, and are reluctant to cross large areas lacking cover. The population at Tower Hill is thus effectively closed to natural emigration and immigration, owing to the expanse of surrounding open habitat.

An overabundance of Eastern Grey Kangaroos at Tower Hill has the possibility to fulfill all of the problems of overabundance outlined by Caughley (1981). Tower Hill is an ecotourist destination, and there is concern about the possibility of injury to visitors. In addition, increased grazing pressure by overabundant kangaroos is likely to affect other ground dwelling herbivores and also have a negative effect on native flora, leading to decreased species diversity within the reserve. As has already been witnessed at Tower Hill with the Koala population, overabundance and the inability of animals to emigrate out of the system to find food may see an increase in mortality due to starvation. Recently, Tower Hill managers and 'Friends of Tower Hill' have become concerned about the number of kangaroos present in the reserve. Despite this, the population has never been properly surveyed. Available records are sporadic and do not account for the possibility of double counting; therefore, estimates of population size are unreliable for management assessment.

The objectives of this study were firstly, to obtain an accurate population count of Eastern Grey Kangaroos in the reserve; secondly, to determine population structure with the aim of establishing the likely growth trajectory of the population; and thirdly, to assess habitat usage. Overall, the aim of this study was to provide information for the management of the population of Eastern Grey Kangaroos at Tower Hill State Game Reserve.

Study area and methods

Tower Hill State Game Reserve is located about 15 km northwest of Warnambool, Victoria. Tower Hill is an extinct volcanic crater of approximately 3 km diameter (Morgan 1997). The total land area of the study site is 264 ha, partitioned into the Main Island (125 ha), Fairy Island (18 ha), Hat Island (1 ha) and the crater rim (120 ha).

This small reserve is isolated from other areas of native vegetation by farmland pasture and a steep crater rim. By the end of the 19th century it was completely cleared for agriculture. In 1961, the decision was made to regenerate this area as a State game reserve. Regrowth throughout the reserve can be classified into five major vegetation types: Eucalypt forest, predominantly *Eucalyptus viminalis;* Eucalypt woodlands, dominated by *E. viminalis* and *E. ovata*; *Allocasuarina* woodlands, dominated by *A. verticillata* and *A. stricta*; shrublands dominated by *Acacia mearnsii*, *A. decurrens* and *A. melanoxylon*; and grasslands.

This study was conducted during May and June 1999. Sampling of the kangaroo population was undertaken using a grid system of 15 transect lines running east-west across the main island of the reserve (Fig. 1; Morgan 1997) and by 4WD along the tracks around the outer rim of the reserve. Transects were mapped out by the authors, 160 m apart (as in the Koala survey of Morgan 1997) and, before data collection, transects were walked on the relevant east or west compass bearing, and marked using flagging tape.

Over the course of this study, each line was walked three times, always between 1000 and 1600 hours. Odd lines were walked in succession, followed by evens, to minimise the possibility of double counting created when animals moved between lines. The observer set off from the beginning of each transect and walked at a constant speed. When a kangaroo group was observed in front of the observer, the following data were recorded: the number of kangaroos in the group; the distance from the observer to the centre of the group (measured with a rangefinder); the compass bearing from the observer to the centre of the group; the sex, if determinable, of the individuals within the group, along with the reproductive status of females; and the habitat type in which the group was observed.

The outer rim was sampled by observation from a vehicle. Established tracks were driven in a 4WD vehicle between 1630 and 1730 hours. When a group was observed, the number of individual kangaroos was recorded along with sex and reproductive status of females, in the hope

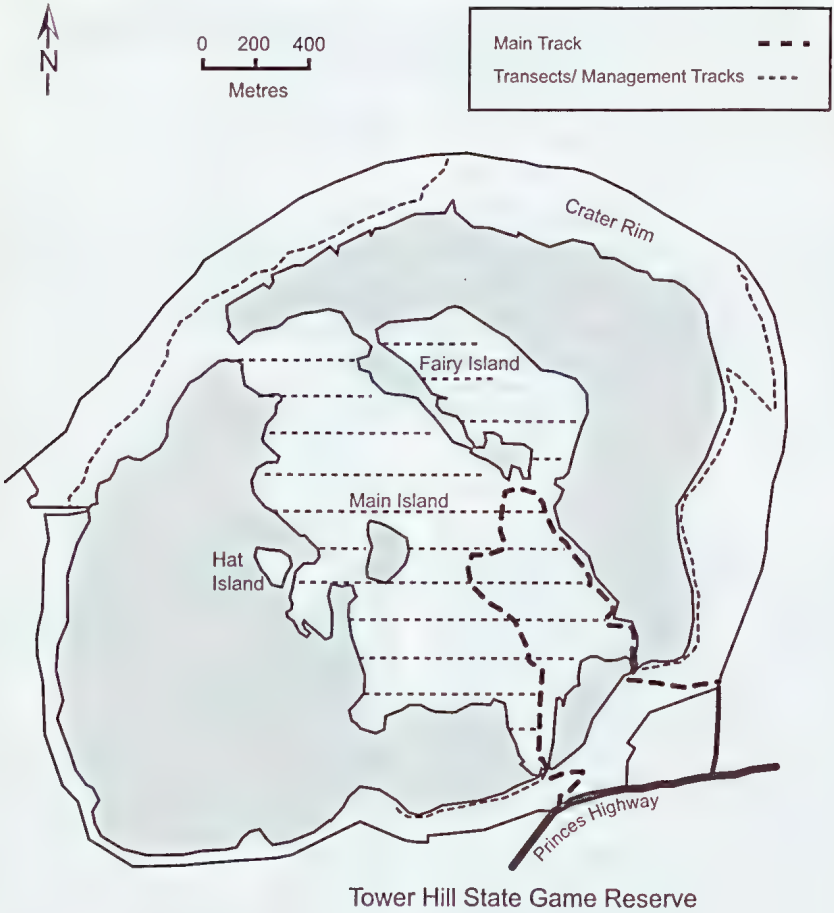

Fig. 1. Map of Tower Hill showing grid system of transects (adapted from Morgan 1997).

of establishing a maximum stable number for the outer rim population. If animals moved extensive distances out of sight, they were not recorded. This was done to minimise the chance of double counting.

The percentage of each habitat type within the reserve was estimated from an aerial photo. Using 1 mm graph paper, habitat percentages were calculated from the number of squares within the reserve occupied by each habitat.

Results

The population density (kangaroos/km^2) was estimated using the computer program MNPS (see Morgan 1986). This program estimates population density and three other parameters from a set of frequency distributions: a coefficient of conspicuousness (in this study 12.91 ± 1.724 m), the lateral vegetation cover (0.05317 ±0.007573), and the maximum direct-line distance at which species recognition is possible (dmax).

The minimum detection distance was 8 m, whilst the maximum (dmax) was 300 m. The highest frequency of kangaroo groups was observed at 23 m. The sighting distance and the curve of the model fitted to those data are shown in Fig. 2.

From this set of data, a density of 81.4 ± 3.54 kangaroos/km^2 (mean ± SE) was estimated. The population for the main island

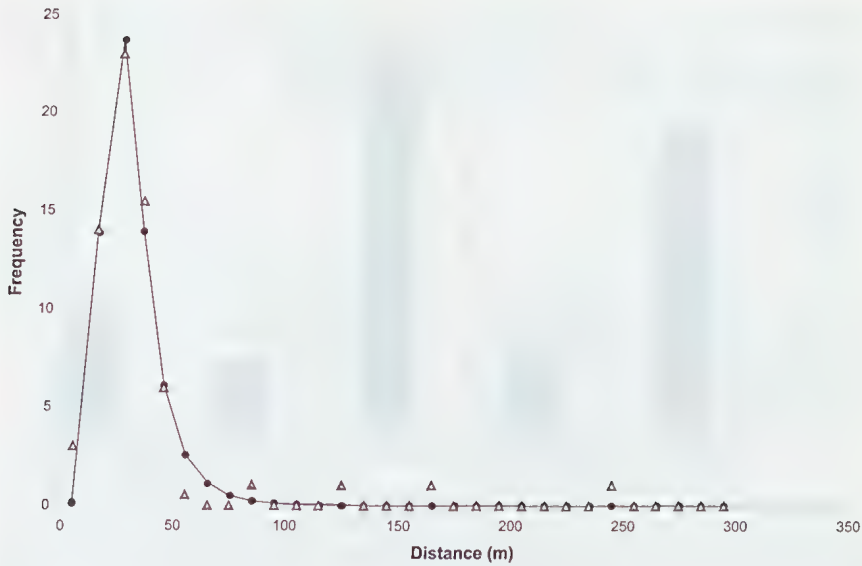

Fig. 2. Frequency distribution of sighting distances from the observer to the kangaroo groups. Triangles indicate actual data points and the line indicates the curve of best fit using the computer program MNPS (Morgan 1986).

was calculated by multiplying the estimated density by the area of the main island, giving an estimate of 117 individuals (Table 1). The stable number observed for the outer rim of the reserve, which was taken as the maximum number observed over the four counts, was 34 (Table 1). The overall estimate for the reserve was 151, with narrow confidence intervals (Table 1).

The minimum percentage of adult females breeding in the population was 71%. The percentage of males within the sample was 54%. A chi-squared test found that the sex ratio of adults in the population did not differ from parity ($\chi^2 = 0.00$, $p > 0.05$, $df = 94$).

The pattern of percentage use of the five defined habitats by this population can be seen in Fig. 3. A chi-squared test was done comparing raw frequencies observed in each habitat with expected frequencies calculated from the availability of each habitat (Set 1 - fine conditions: $\chi^2 = 9.63$, $p < 0.05$, $df = 4$; Set 2 - wet-windy conditions: $\chi^2 = 21.98$, $p < 0.05$, $df = 4$; Table 2). The null hypothesis assumes that habitats were used in proportion to availability. Both analyses rejected the null hypothesis, and show that kangaroos were not using habitats in proportion to their availability. Differences between the two sets are observed within the selection of woodlands and shrublands. Set 1 shows an observed usage of shrublands less then expected and an increased usage of *Allocasuarina* woodlands in fine conditions. In comparison, set 2 shows an increased usage of shrublands and decrease in the use of eucalypt woodlands on days of wet and windy conditions (Table 2).

Table 1. The population estimates (± standard error) and 95% confidence intervals for Eastern Grey Kangaroo *Macropus giganteus* at Tower Hill State Game Reserve.

	Estimated Population	95% CI
Main Island	117 ± 5	107 to 127
Maximum stable number for outer rim population	34	-
Overall (for outer rim and main island)	151	141 to 161

Discussion

This study shows that the population of Eastern Grey Kangaroos at Tower Hill State Game Reserve has increased from a minimum of 19, between 1979 and 1985,

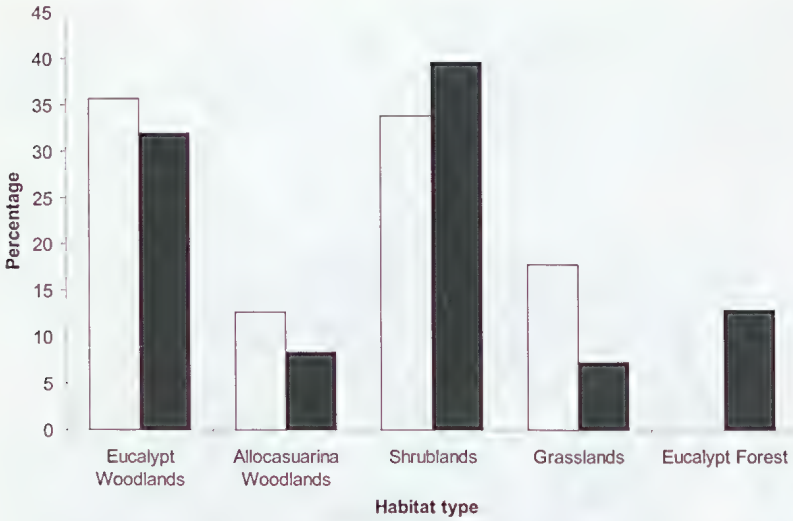

Fig. 3. The percentage of the five main habitats within the reserve (shaded) and the percentage of Eastern Grey Kangaroos *Macropus giganteus* observed within these habitats (unshaded).

to an estimate of 151 in 1999. This estimate suggests that the population has increased dramatically. Along with this growth witnessed over the past 14 years the demographics of the population at Tower Hill suggest that there is potential for continued growth in the future. The rate of increase of a population depends upon its current age distribution and sex ratio (Bayliss 1985; Caughley *et al.* 1987). This population showed no apparent sex-biased mortality in adult individuals with the sex ratio of adults being at parity. Norbury *et al.* (1988) noted a female bias in Western Grey Kangaroos *M. fuliginosus melanops* after drought, resulting in a decreased growth trajectory. However, parity or male biased populations are thought to be indicative of growing populations (Norbury *et al.* 1988).

The population of kangaroos at Tower Hill also had a high percentage of breeding females, with a minimum of 71% of adult females carrying young. Females with very small pouch young are extremely difficult to identify as breeding individuals; consequently, this figure is likely to underestimate the breeding potential of the population. Kangaroos may respond to changes in rate of population increase by adjusting their rates of reproduction (Bayliss 1985; Caughley *et al.* 1987). In harsh conditions, kangaroos have been shown to have a dramatically reduced fecundity (Norbury *et al.* 1988). Continued growth of the Tower Hill population can be expected, as a high percentage of the females are breeding.

Overabundance of any grazing or browsing species has the potential to be devastating to the vegetation within any reserve. Research at other sites has shown that overgrazing by kangaroos can have a negative effect on the structure and floristics of ground cover and on soil invertebrates and ground-dwelling birds (e.g. Neave and Tanton 1989; Coulson 1998). In these areas, removal of kangaroos had a marked effect on the regeneration of native ground vegetation and dicotyledon species (Neave and Tanton 1989; Coulson 1998). Since Tower Hill's classification as a State Game Reserve in 1961, a great deal of effort has gone into the re-establishment of indigenous vegetation on this once cleared site. Overgrazing by Eastern Grey Kangaroos may threaten the continued success of this revegetation effort.

In this study, kangaroos actively selected habitats, although the preferences shifted depending on the environmental conditions. Selection, it seems, was affected by the need for shelter from the elements. For example, when environmental conditions were harsher, more time was spent in

Table 2. The frequency of kangaroos observed in each habitat and the expected frequency according to the proportion of the reserve occupied by each habitat type.

Habitats	Eucalypt Woodland	Allocasuarina Woodland	Shrubland	Grassland	Eucalypt Forest
Set 1 (fine conditions)					
Observed	23	13	10	14	0
Expected	21	8	20	11	0.5
Set 2 (wet-windy conditions)					
Observed	7	9	37	12	0
Expected	23	8	22	12	0.5

shrublands of greater density where there is more cover than in open woodlands. Such results are important to consider when contemplating management of the reserve. Time and money should be invested in the rehabilitation and protection of areas of the reserve at greatest risk. For example, in cooler months, increased management of over-used shrubland areas may reduce the impact of kangaroo grazing in the reserve.

It appears that the population of kangaroos at Tower Hill State Game Reserve has increased dramatically and will continue to increase. The first step in assuring the effective management of the Tower Hill population should be to outline the issues within the reserve that are of management priority. With management priorities clearly stated, an appropriate management plan should be designed to effectively maintain these goals. The management plan should determine an optimal population size of kangaroos within the reserve. Appropriate methods of control should be investigated, and consideration given to use of concurrent methods such as exclusion fencing, culling and fertility control.

This study has been the first comprehensive study completed on the kangaroo population at Tower Hill since their reintroduction in 1964. Results have shown that numbers in the reserve have increased dramatically and in light of the population demography, have the potential to increase further, thereby threatening the biodiversity of the reserve. Further study, and development of management practices, are essential to ensure that efforts already put into the reserve by staff, Friends and the community have not been in vain.

Acknowledgements

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All the hard work that went into this study and into this final report is dedicated to John McCulloch.

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Potential Dispersal Agents of Higher Plants in the Kosciuszko Alpine Area

Karen C Rudkin[1] and Catherine M Pickering[1,2]

Abstract
Morphology of higher plants in the Kosciuszko alpine area was investigated in order to determine probable dispersal agents. Attributes including seed and fruit morphology, presentation mechanisms and habitat for each plant were matched to ecological syndromes representing four primary dispersal agents: wind, water, animals and the plant itself. The most common probable dispersal agent was wind, followed by animal, water and parent dispersal. (*The Victorian Naturalist* **119** (6), 2002, 258-268)

Introduction

Dispersal mechanisms in plants have been the subject of extensive theoretical and empirical research, much of which has concentrated on the anatomical structure of the dispersal unit or diaspore i.e. the seed, fruit, spores and/or vegetative parts (see reviews by van der Pijl 1982; Murray 1986). Several criteria can be used to classify dispersal methods (Dansereau and Lems 1957, cited in van Rheede van Oudtshoorn and van Rooyen 1999), although the system most commonly applied is that of Ridley (1930) using the agent of transport as the criterion (e.g. van Rheede van Oudtshoorn and van Rooyen 1999). In this system, dispersal traits representing ecological 'syndromes' are matched to the most effective dispersal agent (Ridley 1930; van der Pijl 1982). This may involve a single trait, although in most cases it is a combination of characteristics (van der Pijl 1982). For example, plants growing in open habitats with capsules set upon elongated stalks that open to release small mature seeds when humidity is low are considered to be wind dispersed (van der Pijl 1982).

Principle transport agents of plant diaspores are animals, wind, water and the parent plant itself, with the resulting dispersal mechanisms termed zoochory, anemochory, hydrochory and autochory respectively (van Rheede van Oudtshoorn and van Rooyen 1999). Wind is considered the 'basic' dispersal mechanism (Sernander 1927, cited in van der Pijl 1982), although in ferns and conifers, animal dispersal was found to be dominant (van der Pijl 1982). Wind is a common dispersal mechanism in open habitats and regions characterized by severe climates and limited numbers of animal vectors (van der Pijl 1982). In regions with few animal dispersal agents, the flora may show a range of traits for wind and water dispersal (Ridley 1930). In mountainous areas, mammal, bird and insect diversity tends to decline as altitude increases (Meyer and Thaler 1995). Around Mt Kosciuszko, the largest continuous alpine area in Australia, there appear

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Table 1. Animals of Kosciuszko alpine area with potential to act as dispersal agents for flora. R, alpine resident; S, reside in the alpine area during the warmer months only; * introduced species.

Taxon	Status	Habits/Diet	References
Mammals			
Burramys parvus Mountain Pygmy-possum	R	Hibernates during winter, diet includes cached seeds eg. Alpine Hovea *Hovea montana* and Mountain Plum Pine *Podocarpus lawrencei*	Mansergh *et al.* 1990; Green and Osborne 1994
Antechinus spp. Brown and Dusky Antechinus	R	Small marsupial, insectivore, occurs in moister areas where adequate ground cover of shrubs exist	Dimpel 1976; Green 1989
Mastacomys fuscus Broad-toothed Rat	R	Mainly herbivorous, takes small amounts of seeds, builds nests from grass	Carron *et al.* 1990
Rattus fuscipes Southern Bush Rat	R	Found in woodland, heath and grassland, in winter moves to alpine herbfield. Diet diverse including seeds, dicots taken year round, monocots in late autumn and winter	Carron *et al.* 1990
*Vulpes vulpes** Red Fox	R	Diet: insects, mammals and minimal vegetable matter	Green and Osborne 1981
Birds			
Anas superciliosa Pacific Black Duck	S	Found near water, feeds mainly on seeds and vegetable matter	Frith 1986
Gallinago hardwickii Latham's Snipe	S	Feeds in fens, bogs and wet grassland on seeds and invertebrates	Green and Osborne 1994
Anthus novaeseelandiae Richard's Pipit	S	Tall alpine herbfield and tussock grassland, eats insects and small seeds, grass lined nest situated in thick vegetation e.g. *Richea continentis*	Green and Osborne 1994
Zosterops lateralis Silvereye	S	Nest of grass, feeds on insects, nectar and berries	Green and Osborne 1994
*Sturnus vulgaris** Common Starling	S	Nest of grass, feeds on insects and plant foods on the ground or in trees	Green and Osborne 1994
Coturnix pectoralis Stubble Quail	S	Nests on the ground in grass lined depression, feeds on seeds, green grass and insects	Cayley 1975
Ants			
Iridomyrmex spp.	R	Omnivorous, can be found in dry and wet habitats eg. bogs, tracks, herbfield and grassland	Green and Osborne 1994

to be few animal agents for seed dispersal (Table 1). In contrast, much of the area consists of wind exposed slopes or valley floors with creeks, fen or bogs (Costin *et al.* 2000), providing opportunities for dispersal by wind and water. In addition, particularly in harsh environments, optimal dispersal may not require maximizing distance, as the most suitable habitat may be more readily available close to the parent plant (Ellner and Shmida 1981).

To better understand the role of seed dispersal in the ecology of the Kosciuszko alpine zone, this review identifies morphological dispersal characteristics for all seed plants recorded in the region and matches them to potential dispersal agents.

Methods

Study area

The Kosciuszko alpine area extends from the treeline at around 1830 m above sea level to the top of Australian's highest mountain (Mt Kosciuszko: 2228 m ASL) an area of approximately 100 km^2 (Costin *et al.* 2000). This area contains the most diverse alpine environment on the mainland with 204 native angiosperm taxa from 40 families, one gymnosperm species and fourteen introduced species of angiosperms (Costin *et al.* 2000). Plants exhibit a range of growth forms including shrubs, grasses, sedges, rushes, herbs, mats and cushions, with herbs the most dominant.

Table 2. Dispersal syndrome used for alpine flora of Kosciuszko National Park for the four primary dispersal agents for seed bearing plants.

Dispersal syndrome	Dispersal syndrome characteristics *General*	*Poaceae*
Anemochory (wind)	Dust-like seeds	Hairs present on lemma and/or palea
	Fruit on long peduncles	Bearded callas
	Peduncles elongate during fruit maturation	Awn present
	Dry fruits that dehisce in dry air	Plumose rachilla
	Predominantly small herbaceous species	
	Small (<1mm), plumed, winged or ribbed seeds	Open habitats
Hydrochory (water)	Diaspores without other mechanisms (>1mm)	Glabrous lemma, palea and/or callas
	Dry fruits that dehisce in moist air	Bristled rachilla, habitat near water-course
	Floating utricle or loose seed coat	
	Seed coat to prevent germination during transport	Spikelets droop at maturity, fine hairs on lemma
	Moist or low-lying habitat	Absence of awn and/or rachilla
	Low-growing	
Zoochory (animal)	Fruit berry, drupe or nut	Barbed callas
	Fruit or seed colour red, black or purple	Spiked or scabrous lemma and/or palea
	Burred, scabrous, hooked, or sticky diaspore	
	Elaiosome present on seed	Presence of mucro
	Small (<1mm) and/or scabrous diaspore	Large floret (>5mm), glabrous lemma
	Moist habitat	
		Short rigid awn, bristled rachilla
Autochory (parental plant)	Explosive dehiscence of capsule or follicle	

Classification of dispersal syndrome

Due to the number of taxa to be studied and diversity of structures associated with dispersal, classification by agent dispersal syndromes was limited to the four principal agents of dispersal (after Ridley 1930; Table 2). Criteria used to classify taxa were based on (1) seed morphology including structures attached to or enclosing seed, (2) plant habitat, and (3) seed presentation (where on parent plant). Some difficulties were encountered in applying the criteria to the specialized structures of grasses (Poaceae); therefore, these taxa were considered separately (Table 2). Morphological characteristics for the seed plants of Kosciuszko alpine area were identified from taxonomic descriptions by Costin *et al.* (2000), Harden (2000) and Walsh and Entwisle (1999). Native flora and introduced weed species were categorized separately. When attributes of a species could be attributed to more than one agent syndrome, a subjective decision was made as to the 'most likely' dispersal agent based on the combination of attributes.

Results

The major potential dispersal agent was identified for each of the 205 native taxa (Appendix 1) and 14 introduced species (Appendix 2). For the native taxa, the most common agent was wind (anemochory, 114 taxa), followed by animals (zoochory, 53), water (hydrochory, 34) and the parent plant (autochory 4; Fig. 1). The dominance of wind dispersed seeds was due to the prevalence of herbs with small plumed, winged or ribbed seeds (Fig. 2), which together accounted for 73 (35%) of the total native taxa.

Growth forms typically associated with wet habitats such as sedges and rushes were characterized by water and animal dispersal (Fig. 2) while low-growing cushions and mat/herbs were wind dispersed. Taxa with shrub/subshrub growth forms (Epacridaceae) were also wind dispersed. Of the grasses, 47.8% are likely to be wind dispersed, with the remaining 52.2% divided evenly between both water and animal dispersal. Animal dispersal was the determined agent for the three dwarf shrubs Alpine Ballart *Exocarpus nanus* (Santalaceae), Alpine Kelleria *Kelleria dieffenbachii* (Thymelaeaceae) and Alpine Rice-Flower *Pimelea alpina* (Thymelaeaceae).

The most probable dispersal agent of the single representative of Gymnospermae, Mountain Plum Pine *Podocarpus lawrencei*

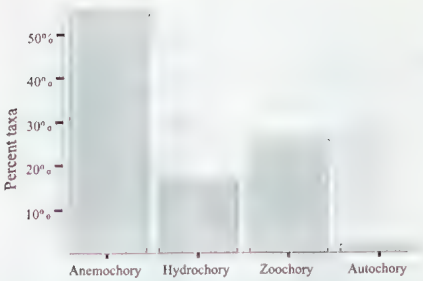

Fig. 1. Native taxa recorded in the Kosciuszko alpine area attributed to the four probable dispersal agents. Anemochory = wind, hydrochory = water, zoochory = animal, autochory = parental plant. n = 205.

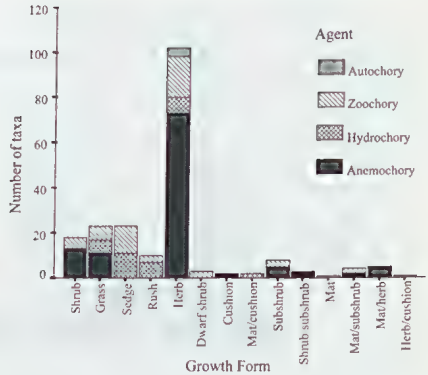

Fig. 2. Probable dispersal agents of native taxa (in terms of growth forms) of the Kosciuszko alpine area (Costin *et al.* 2000).

was found to be zoochory. Seeds of this species are included in the diet of the Mountain Pygmy Possum *Burramys parvus*, known for their habit of caching seeds in and around nests (Table 1). Within angiosperms, seed dispersal by animals was found in four of the six monocot families (40% of taxa) and thirteen of the thirty-two dicot families (20% of taxa). Of the native taxa likely to have diaspores dispersed by animals, 57% had characteristics indicating dispersal that involved viable seed being eaten and excreted undamaged. The remaining 43.4% had sticky, hooked or burred seeds likely to be dispersed by animals externally (e.g. carried on fur; Fig. 3).

An alternative method for animals to carry seed externally was identified by Ridley (1930) where the small otherwise un-mechanized seeds of Juncaceae were transported from one area to another in mud sticking to the feet of waterfowl. This may be the method of seed dispersal for *Juncus antarcticus, J. falcatus* and *J. thompsonianus* in the Kosciuszko alpine area, as the plants invariably grow in marshy spots where they may come into contact with the feet or plumage of the Pacific Black Duck *Anas superciliosa* residing in the area over summer (Table 1). However, the small seed size, presentation mechanism and growth form of these taxa also suggests dispersal by wind.

The six remaining taxa of the family Juncaceae are comprised of the genus *Luzula*, many of which were also found near water, and their larger seed size (1.0-1.8 mm) indicates water dispersal. Interestingly, many species of *Luzula,* including one species found in this region, *Luzula acutifolia* subsp. *nana,* have a small fleshy outgrowth of the seed coat (caruncle). These structures on *Luzula multiflora* were found to be attractive to ants (Ridley 1930), which transport the seeds short distances. Ridley (1930) also recorded finding *Luzula* inflorescences, with seed, used as nesting material by sparrows; however, this has yet to be determined for the species considered here and is unlikely to account for the wide distribution of these plants as there are few bird species, and no sparrows.

Herbs comprised 55.6% of all native taxa (Costin *et al.* 2000). Taxa from common herb families such as the Asteraceae and Apiaceae were determined to potentially be wind dispersed, as were those of Orchidaceae, Crassulaceae, Geraniaceae, Onagraceae, Gentianaceae, Scrophulariaceae, Plantaginaceae, Campanulaceae and Stylidiaceae (Fig. 4). Herbs also accounted for all species classed as autochores (mechanical self dispersal) comprising the three *Cardamine* spp. (Brassicaceae) and the Violet *Viola betonicifolia* subsp. *betonicifolia*, each characterized by explosive seed capsules.

There were fourteen established introduced weed species in five families, and all but one were classified as wind dispersed (Fig. 5). Timothy grass *Phleum pretense* (Poaceae) was classified animal dispersed primarily due to the thin and dry outermost bract of the floret lemma extending as a point. Ridley (1930) cited several examples of viable seeds of this species being dispersed

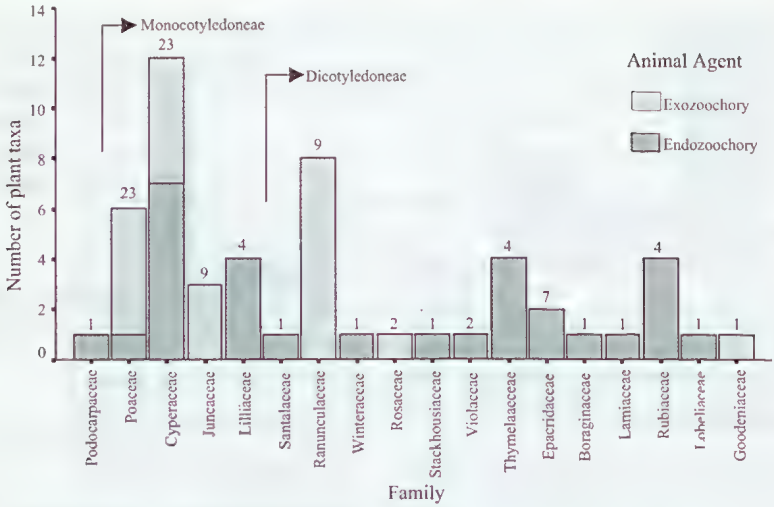

Fig. 3. Number of taxa in each family exhibiting characteristics that indicate seed dispersal by animals. Endozoochores transport seeds internally, excreting them undamaged. Seed transport on the fur or plumage of animals are classified exozoochores. Numbers at the top of each column indicate the total number of native taxa in each family recorded in the Kosciuszko alpine area.

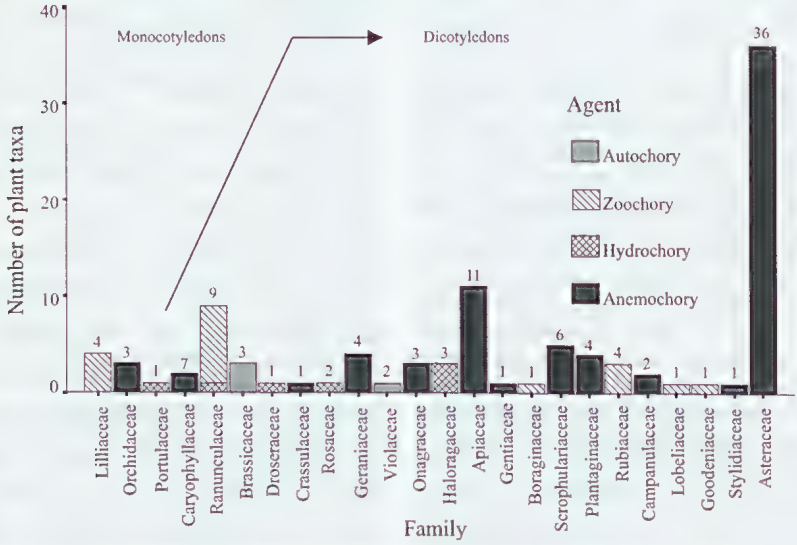

Fig. 4. Number of native herbs by family recorded in the Kosciuszko alpine area (Costin *et al.* 2000) attributed to the four probable dispersal agents. Numbers at the top of each column indicate the total number of native taxa in each family recorded in the Kosciuszko alpine area.

by cattle and horses, both of which were present in the alpine area until recently.

Discussion

The diversity of alpine diaspore structures and presentation at maturity presumably increase the chance of seeds being favourably dispersed (Ridley 1930). However, many of the species studied in the Kosciuszko alpine area had little or no apparent adaptations for diaspore dispersal based on morphological descriptions of seed in Floras. More detailed examination of material and field work may clarify this. Complications also arose in seeds adapted

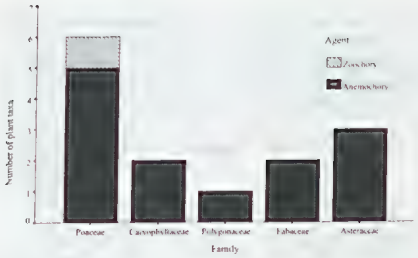

Fig. 5. Number of introduced weed taxa by family recorded in the Kosciuszko alpine area (Costin *et al.* 2000) attributed to the probable dispersal agents. n = 14.

for several agents of dispersal, or for a succession of agents (Ridley 1930; van Rheede van Oudtshoorn and van Rooyen 1999). For example, feathery hairs on seed can be dispersed by wind, provide buoyancy in water, facilitate adherence to animals, and assist with anchorage to the ground during germination (Ridley 1930). It has also been demonstrated that the awn of barley is an important photosynthetic structure, suggesting the diaspores may have functions other than just dispersal (van der Pijl 1982). Therefore by assigning seed to a single agent, we may have underestimated animal, water and plant dispersal mechanisms.

Conditions favorable for growth in alpine environments are often restricted to small micro-habitats. Seed morphologies that restrict dispersal to the vicinity of the parent plant may therefore be advantageous (van der Pijl 1982). Zohary (1962, cited in van Rheede van Oudtshoorn and van Rooyen 1999) distinguished two major categories of localized dispersal; 1) restriction of dispersal in space and 2) restriction of dispersal in time. The former includes burying of seed or formation of fruits immediately above the ground, limiting separation of seed, and the presence of sticky material (mucilage), burrs or other anchorage mechanisms on the seed. Inhibitory mechanisms of the latter include postponement of dispersal until the following season, and opening or closing of the dispersal organ (e.g. capsule or follicle) as a function of moisture. The taxonomic descriptions available did not include enough information to make determinations as to the presence or absence of these types of mechanisms, nor did they provide post-dispersal details e.g. weight, buoyancy, absorbency of seed coat, hydrophilic nature of hairs, etc.

This study provides information about potential dispersal mechanisms. Observations of species growing in the natural habitat are required to confirm the potential dispersal mechanisms proposed. This also includes examining the role of vegetative dispersal mechanisms such as the transport of torn-off rhizomes, stems and stolons. Based on the data presented here, however, we can conclude that wind appears to be the most common type of dispersal mechanism for the Kosciuszko alpine flora.

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Appendix 1. Native gymnosperm and angiosperm species, subspecies and varieties recorded from the Kosciuszko alpine area including growth form and habitats as recorded by Costin *et al.* (2000). Habitat abbreviations: B, bog; F, fen; FMa, feldmark (*Epacris-Chionohebe* alliance); FMb, (*Coprosma-Colobanthus*) alliance; H, heath; STG, sod tussock grassland; SAH, short alpine herbfield; TAHa, tall alpine herbfield (*Celmisia-Poa* alliance); TAHb, tall alpine herbfield (*Brachyscome-Austrodanthonia* alliance). Zoochory* indicates endozoochory; Zoochory** indicates exozoochory; • endemic to Kosciuszko alpine area.

	Species	Common Name	Growth Form	Habitat	Probable Dispersal Agent
	Gymnospermae				
	Podocarpaceae				
1	*Podocarpus lawrencei*	Mountain Plum-pine	Shrub	H	Zoochory*
	Angiospermae: Mononcotyledoneae				
	Poaceae				
2	*Agrostis meionectes*	Alpine Bent	Grass	STG, SAH, F, B	Anemochory
3	*Agrostis muelleriana*	Mueller's Bent	Grass	TAHa, STG, F, B, FMa	Hydrochory
4	*Agrostis parviflora*	Hair Bent	Grass	?	Anemochory
5	*Agrostis venusta*	Graceful Bent	Grass	TAHa, STG	Anemochory
6	*Agrostis* sp.	Swamp Bent	Grass	STG, F, B, TAHa	Hydrochory
7	*Australopyrum velutinum*	Mountain Wheat-grass	Grass	TAHa, STG	Zoochory**
8	*Austrodanthonia alpicola*	Crag Wallaby-grass	Grass	TAHb	Anemochory
9	*Chionochloa frigida* •	Ribbony grass	Grass	TAHa	Anemochory
10	*Deschampsia caespitosa*	Tufted Hair-grass	Grass	STG	Anemochory
11	*Deyeuxia affinis*	Dwarf Bent-grass	Grass	SAH	Zoochory**
12	*Deyeuxia carinata*	Slender Bent-grass	Grass	STG, F, B, H	Zoochory**
13	*Deyeuxia crassiuscula*	Coarse Bent-grass	Grass	TAHa, STG	Zoochory**
14	*Deyeuxia monticola* var. *monticola*	Mountain Bent-grass	Grass	STG, TAHa	Zoochory**
15	*Hierochloe submutica*	Alpine Holy-grass	Grass	TAHa	Hydrochory
16	*Poa costiniana*	Prickly Snow-grass	Grass	STG, F, B, TAHa	Hydrochory
17	*Poa fawcettiae*	Smooth-blue Snow-grass	Grass	TAHa, STG	Anemochory
18	*Poa hiemata*	Soft Snow-grass	Grass	TAHa	Anemochory
19	*Poa saxicola*	Rock Poa	Grass	TAHa	Zoochory*
20	*Rytidosperma australe*	Snowpatch grass	Grass	SAH	Hydrochory
21	*Rytidosperma nivicola*	Snow Wallaby-grass	Grass	STG, TAHa, F	Anemochory
22	*Rytidosperma nudiflorum*	Alpine Wallaby-grass	Grass	STG, TAHa, F	Anemochory
23	*Rytidosperma pumilum*	Feldmark grass	Grass	FMa	Hydrochory
24	*Trisetum spicatum* subsp. *australiense*	Bristle-grass	Grass	TAHa, STG	Anemochory
	Cyperaceae				
25	*Carex archeri*	Archer's Sedge	Sedge	B	Hydrochory
26	*Carex breviculmis*	Short-flower Dryland Sedge	Sedge	TAHa, STG	Hydrochory
27	*Carex canescens*	Yellow-headed Sedge	Sedge	F, B, TAHa, STG	Hydrochory
28	*Carex cephalotes*	Button Sedge	Sedge	F, B, SAH, STG	Hydrochory
29	*Carex echinata*	Star Sedge	Sedge	SAH, TAHa, B	Hydrochory
30	*Carex gaudichaudiana*	Tufted Sedge	Sedge	F, B, STG	Hydrochory
31	*Carex hebes*	Dryland Sedge	Sedge	TAHa, STG	Hydrochory
32	*Carex hypandra*	Dark Fen-sedge	Sedge	F, B	Hydrochory
33	*Carex jackiana*	Short-flower Swamp Sedge	Sedge	SAH, B, F, STG	Hydrochory
34	*Carpha alpina*	Small Flower-rush	Sedge	STG, F, B	Hydrochory
35	*Carpha nivicola*	Broad-leaf Flower-rush	Sedge	F, B	Hydrochory
36	*Isolepis aucklandica*	Slender Club-rush	Sedge	SAH, B, F	Zoochory*
37	*Isolepis crassiuscula*	Alpine Club-rush	Sedge	SAH, TAHa	Zoochory*
38	*Isolepis habra*	Tufted Club-rush	Sedge	B	Zoochory*
39	*Isolepis montivaga*	Mountain Club-rush	Sedge	SAH, F, STG	Zoochory*
40	*Isolepis subtilissima*	Dwarf Club-rush	Sedge	SAH	Zoochory*
41	*Oreobolus distichus*	Fan Tuft-rush	Sedge	B, SAH, TAHa	Zoochory*
42	*Oreobolus pumilio* subsp. *pumilio*	Alpine Tuft-rush	Sedge	SAH, F	Zoochory*
43	*Schoenus calyptratus*	Alpine Bog-rush	Sedge	SAH	Zoochory**
44	*Uncinia compacta*	Compact Hook-sedge	Sedge	TAHa, STG	Zoochory**
45	*Uncinia flaccida*	Mountain hook-sedge	Sedge	TAHa, STG	Zoochory**
46	*Uncinia sinclairii*	Sinclair's Hook-sedge	Sedge	STG	Zoochory**
47	*Uncinia sulcata*	Furrowed Hook-sedge	Sedge	TAHa, STG	Zoochory**
	Restionaceae				
48	*Empodisma minus*	Spreading Rope-rush	Rush	B, STG, TAHa	Hydrochory
	Juncaceae				
49	*Juncus antarcticus*	Cushion Rush	Rush	SAH, B	Zoochory**
50	*Juncus falcatus*	Sickle-leaf Rush	Rush	F, B	Zoochory**
51	*Juncus thompsonianus*	Thompson's Rush	Rush	B, F, SAH	Zoochory**
52	*Luzula acutifolia* subsp. *nana*•	Dwarf Woodrush	Rush	SAH	Hydrochory
53	*Luzula alpestris*	Mountain Woodrush	Rush	STG, TAHa	Hydrochory

Appendix 1 continued.

	Species	Common Name	Growth Form	Habitat	Dispersal
54	*Luzula atrata*	Slender Woodrush	Rush	B, F, SAH	Hydrochory
55	*Luzula australasica* subsp. *dura*•	Feldmark Woodrush	Rush	Fma	Hydrochory
56	*Luzula modesta*	Bog Woodrush	Rush	B	Hydrochory
57	*Luzula novae-cambriae*	Rock Woodrush	Rush	TAHa, H	Hydrochory
	Liliaceae				
58	*Astelia alpina* var. *novae-hollandiae*	Silver Astelia	Herb	B, TAHa	Zoochory*
59	*Astelia psychrocharis* •	Kosciuszko Pineapple-grass	Herb	B, TAHa	Zoochory*
60	*Dianella tasmanica*	Tasman Flax-lily	Herb	TAHa, H	Zoochory*
61	*Herpolirion novae-zelandiae*	Sky Lily	Herb	STG	Zoochory*
	Orchidaceae				
62	*Caladenia alpina*	Alpine Caladenia	Herb	B	Anemochory
63	*Prasophyllum alpestre*	Highland Leek-orchid	Herb	B, TAHa, STG	Anemochory
64	*Prasophyllum tadgellianum*	Tadgell's Leek-orchid	Herb	B, TAHa, STG	Anemochory
	Angiospermae: Dicotyledoneae				
	Proteaceae				
65	*Grevillea australis*	Alpine Grevillea	Shrub	H	Anemochory
66	*Grevillea victoriae* subsp. *nivalis*	Royal Grevillea	Shrub	H	Anemochory
67	*Orites lancifolia*	Alpine Orites	Shrub	H	Anemochory
	Santalaceae				
68	*Exocarpos nanus*	Alpine Ballart	Dwarf Shrub	H, TAHa	Zoochory*
	Portulacaceae				
69	*Neopaxia australasica*	White Purslane	Herb	SAH, TAHa	Hydrochory
	Caryophyllaceae				
70	*Colobanthus affinis*	Alpine Colobanth	Herb	TAHa, FMa	Anemochory
71	*Colobanthus nivicola* •	Snowpatch Cushion	Cushion	FMb, SAH, TAHa	Anemochory
72	*Colobanthus pulvinatus*	Feldmark Cushion	Cushion	FMa, TAHa	Anemochory
73	*Scleranthus biflorus*	Twin-flower Knawel	Mat/Cushion	TAHa, STG	Hydrochory
74	*Scleranthus brockiei*	Brockie's Knawel	Mat/Cushion	TAHa	Hydrochory
75	*Scleranthus singuliflorus*	One-flowered Knawel	Herb/Cushion	TAHa, STG, FMa	Hydrochory
76	*Stellaria multiflora*	Rayless Starwort	Herb	TAHa	Anemochory
	Ranunculaceae				
77	*Caltha introloba*	Alpine Marsh-marigold	Herb	SAH	Hydrochory
78	*Ranunculus acrophilus* •	Feldmark Buttercup	Herb	FMa	Zoochory**
79	*Ranunculus anemoneus* •	Anemone Buttercup	Herb	FMb, TAHa, SAH	Zoochory**
80	*Ranunculus dissectifolius* •	Feather Buttercup	Herb	TAHa, STG, H	Zoochory**
81	*Ranunculus graniticola*	Granite Buttercup	Herb	TAHa, STG	Zoochory**
82	*Ranunculus gunnianus*	Gunn's Alpine Buttercup	Herb	TAHa, STG	Zoochory**
83	*Ranunculus millanii*	Dwarf Buttercup	Herb	STG, F, B	Zoochory**
84	*Ranunculus muelleri*	Felted Buttercup	Herb	TAHa, STG	Zoochory**
85	*Ranunculus niphophilus* •	Snow Buttercup	Herb	SAH, TAHa	Zoochory**
	Winteraceae				
86	*Tasmannia xerophila* subsp. *xerophila*	Alpine Pepper	Shrub	H	Zoochory*
	Brassicaceae				
87	*Cardamine astoniae*	Aston's Bitter Cress	Herb	B	Autochory
88	*Cardamine lilacina* s.l.	Native Bitter Cress	Herb	STG, TAHa	Autochory
89	*Cardamine robusta* •	Snow Bitter Cress	Herb	SAH, TAHab	Autochory
	Droseraceae				
90	*Drosera arcturi*	Alpine Sundew	Herb	B, SAH	Hydrochory
	Crassulaceae				
91	*Crassula sieberiana* s.l.	Austral Stonecrop	Herb	TAHa	Anemochory
	Rosaceae				
92	*Acaena* sp.	Bidgee-widgee	Subscrub	TAHa, H, STG	Zoochory**
93	*Alchemilla xanthochlora* auct.	Lady's Mantle	Herb	TAHab	Hydrochory
	Fabaceae				
94	*Hovea montana*	Alpine Hovea	Shrub	H	Anemochory
95	*Oxylobium ellipticum*	Common Shaggy Pea	Shrub/Subshrub	H	Anemochory
96	*Podolobium alpestre*	Alpine Shaggy Pea	Shrub/Subshrub	H	Anemochory
	Geraniaceae				
97	*Geranium antrorsum*	Rosetted Crane's-bill	Herb	TAHa, STG, B	Anemochory
98	*Geranium potentilloides* var. *abditum*	Mountain Crane's-bill	Herb	TAHa, STG, H	Anemochory
99	*Geranium potentilloides* var.	Alpine Swamp Crane's-bill	Herb	TAHa, STG	Anemochory
100	*Pelargonium helmsii*	Alpine Stork's-bill	Herb	TAHa	Anemochory
	Rutaceae				
101	*Phebalium ovatifolium* •	Ovate Phebalium	Shrub	H	Anemochory

Appendix 1 continued.

Species	Common Name	Growth Form	Habitat	Dispersal
Stackhousiaceae				
102 *Stackhousia pulvinaris*	Alpine Stackhousia	Mat	STG, TAHa	Zoochory*
Violaceae				
103 *Melicytus* sp. (*Hymenanthera* auct.)	Woody Violet	Subshrub	H	Zoochory*
104 *Viola betonicifolia* subsp. *betonicifolia*	Showy Violet	Herb	TAHa, STG	Autochory
Thymelaeaceae				
105 *Kellaria dieffenbachii*	Alpine Kellaria	Dwarf Shrub	FMa	Zoochory*
106 *Pimelea alpina*	Alpine Rice-flower	Dwarf Shrub	TAHa, STG, H	Zoochory*
107 *Pimelea œiflora* subsp. *alpina*	Alpine Bootlace-bush	Subshrub	H, TAHa, STG	Zoochory*
108 *Pimelea ligustrina* subsp. *ciliata*	Kosciuszko Rose	Shrub	H	Zoochory*
Myrtaceae				
109 *Baeckea gunniana*	Alpine Baeckea	Shrub	B, H	Anemochory
110 *Baeckea utilis* var. *utilis*	Mountain Baeckea	Shrub/ Subshrub	H, B	Anemochory
111 *Kunzea muelleri*	Yellow Kunzea	Shrub/ Subshrub	H, STG	Anemochory
Onagraceae				
112 *Epilobium gunnianum*	Gunn's Willow-herb	Herb	TAHa, STG, B, H	Anemochory
113 *Epilobium sarmentaceum*	Mountain Willow-herb	Herb	TAHa, STG	Anemochory
114 *Epilobium tasmanicum*	Snow Willow-herb	Herb	SAH, FMb	Anemochory
Haloragaceae				
115 *Gonocarpus micranthus* subsp. *micranthus*	Creeping Raspwort	Herb	F, B, STG	Hydrochory
116 *Gonocarpus montanus*	Mat Raspwort	Herb	TAHa	Hydrochory
117 *Myriophyllum pedunculatum* subsp. *pedunculatum*	Mat Water-milfoil	Herb	F	Hydrochory
Apiaceae				
118 *Aciphylla glacialis*	Mountain Celery	Herb	TAHa	Anemochory
119 *Aciphylla simplicifolia*	Mountain Aciphyll	Herb	TAHa, STG	Anemochory
120 *Dichosciadium ranunculaceum** var. *ranunculaceum* •	Wreath Pennywort	Herb	SAH, B, TAHa	Anemochory
121 *Diplaspis nivis*	Snow Pennywort	Herb	SAH, B, TAHa	Anemochory
122 *Gingidia algens* •	Kosciuszko Aniseed	Herb	TAHa	Anemochory
123 *Oreomyrrhis brevipes*	Rock Carraway	Herb	TAHa, FMa	Anemochory
124 *Oreomyrrhis ciliata*	Bog Carraway	Herb	B	Anemochory
125 *Oreomyrrhis eriopoda*	Australian Carraway	Herb	TAHa, H	Anemochory
126 *Oreomyrrhis pulvinifica*	Cushion Carraway	Herb	SAH, TAHa	Anemochory
127 *Oschatzia cuneifolia*	Wedge Oschatzia	Herb	TAHa, B	Anemochory
128 *Schizeilema fragoseum*	Alpine Pennywort	Herb	TAHa	Anemochory
Epacridaceae				
129 *Epacris glacialis*	Bog Heath	Shrub/Subshrub	H, B, STG, TAHa	Anemochory
130 *Epacris microphylla* s.l.	Coral Heath	Shrub/Subshrub	FMa, H, B	Anemochory
131 *Epacris paludosa*	Swamp Heath	Shrub	B, H	Anemochory
132 *Epacris petrophila*	Snow Heath	Shrub/Subshrub	FMa	Anemochory
133 *Leucopogon montanus*	Snow Beard-heath	Shrub	H	Zoochory*
134 *Pentachondra pumila*	Carpet Heath	Mat/Subshrub	H, TAHa, STG, FMa	Zoochory*
135 *Richea continentis*	Candle Heath	Subshrub	B	Anemochory
Gentianaceae				
136 *Chionogentias muelleriana* subsp. *alpestris* •	Mueller's Snow-gentian	Herb	STG, TAHa	Anemochory
Boraginaceae				
137 *Myosotis* sp.	Forget-me-not	Herb	TAHab	Zoochory*
Lamiaceae				
138 *Prostanthera cuneata*	Alpine Mint Bush	Shrub	H	Zoochory*
Scrophulariaceae				
139 *Chionohebe densifolia*	Feldmark Snow Hebe	Mat/Subshrub	FMa	Anemochory
140 *Euphrasia alsa* •	Dwarf Eyebright	Herb	FMa, STG, TAHa	Anemochory
141 *Euphrasia collina* var. *diversicolor*	Variable Eyebright	Herb	TAHa, STG, H	Anemochory
142 *Euphrasia collina* subsp. *glacialis* •	Snow Eyebright	Herb	STG, SAH, F, TAHa	Anemochory
143 *Euphrasia collina* var. *lapidosa* •	Feldmark Eyebright	Herb	FMa	Anemochory
144 *Veronica serpyllifolia* s.l.	Thyme Speedwell	Herb	STG, B	Anemochory
Plantaginaceae				
145 *Plantago alpestris*	Veined Plantain	Herb	STG, TAHa	Anemochory
146 *Plantago euryphylla*	Broad Plantain	Herb	STG, TAHa	Anemochory
147 *Plantago glacialis*	Small Star Plantain	Herb	SAH, B	Anemochory
148 *Plantago muelleri*	Star Plantain	Herb	SAH, B	Anemochory

Appendix 1 continued.

Species	Common Name	Growth Form	Habitat	Dispersal
Rubiaceae				
149 *Asperula gunnii*	Mountain Woodruff	Herb	TAHa, STG, H	Zoochory*
150 *Asperula pusilla*	Alpine Woodruff	Herb	TAHa, STG, H	Zoochory*
151 *Coprosma niphophila*	Snowpatch Coprosma	Mat/Subshrub	FMb	Zoochory*
152 *Nertera* sp.	Matted Nertera	Herb	STG, F, B	Zoochory*
Campanulaceae				
153 *Wahlenbergia ceracea*	Waxy Bluebell	Herb	TAHa, STG	Anemochory
154 *Wahlenbergia gloriosa*	Royal Bluebell	Herb	TAHa	Anemochory
Lobeliaceae				
155 *Pratia surrepens* s.l.	Mud Pratia	Herb	F, B, STG	Zoochory*
Goodeniaceae				
156 *Goodenia hederacea* subsp. *alpestris*	Ivy Goodenia	Herb	TAHa	Zoochory**
Stylidiaceae				
157 *Stylidium* sp. (aff. *graminifolium*)	Alpine Trigger Plant	Herb	TAHa, STG, H, B	Anemochory
Asteraceae				
158 *Abrotanella nivigena*	Snow-wort	Mat/Herb	SAH	Anemochory
159 *Brachyscome nivalis*	Snow Daisy	Herb	TAHb	Anemochory
160 *Brachyscome obovata*	Baw Baw Daisy	Herb	TAHa	Anemochory
161 *Brachyscome scapigera*	Tufted Daisy	Herb	TAHa, STG, H, B	Anemochory
162 *Brachyscome spathulata* subsp. *spathulata*	Spoon Daisy	Herb	TAHa, STG, FMa	Anemochory
163 *Brachyscome stolonifera* •	Gwenda's Daisy	Herb	SAH, TAHa, STG	Anemochory
164 *Brachyscome* sp. (aff. *tadgellii*)	Creeping Daisy	Herb	SAH, TAHa	Anemochory
165 *Brachyscome* sp. (aff. *tenuiscapa*)	Mountain Daisy	Herb	STG, TAHa	Anemochory
166 *Celmisia costiniana*	Herbfield Celmisia	Herb	TAHa, STG	Anemochory
167 *Celmisia pugioniformis*	Dagger-leaf Celmisia	Herb	TAHa, STG	Anemochory
168 *Celmisia tomentella*	Bog Celmisia	Herb	B	Anemochory
169 *Cotula alpina*	Alpine Cotula	Herb	B, TAHa, STG	Anemochory
170 *Craspedia alba*	Dwarf Billy-button	Herb	STG	Anemochory
171 *Craspedia aurantia*	Orange Billy-button	Herb	H, TAHa	Anemochory
172 *Craspedia costiniana* •	Hairy Billy-button	Herb	TAHa, STG	Anemochory
173 *Craspedia jamesii*	James's Billy-button	Herb	TAHa, STG	Anemochory
174 *Craspedia lamicola* •	Shiny-leaf Billy-button	Herb	TAHa, STG	Anemochory
175 *Craspedia leucantha*	Pale Billy-button	Herb	SAH, TAHa	Anemochory
176 *Craspedia maxgrayi*	Woolly Billy-button	Herb	TAHa, STG	Anemochory
177 *Craspedia* sp. B	Sticky Billy-button	Herb	TAHab, FMa	Anemochory
178 *Erigeron bellidiodes*	Violet Fleabane	Herb	STG, TAHa	Anemochory
179 *Erigeron nitidus*	Sticky Fleabane	Herb	STG, TAHa	Anemochory
180 *Erigeron paludicola*	Bog Fleabane	Herb	B	Anemochory
181 *Erigeron setosus* •	Dwarf Fleabane	Herb	SAH	Anemochory
182 *Euchiton argentifolius*	Silver Cudweed	Mat/Herb	TAHa, STG	Anemochory
183 *Euchiton fordianus*	Ford's Cudweed	Herb	TAHa, STG	Anemochory
184 *Euchiton nitidulus*	Shining Cudweed	Mat/Herb	STG	Anemochory
185 *Euchiton poliochlorus*	Swamp Cudweed	Herb	B	Anemochory
186 *Euchiton umbricola*	Cliff Cudweed	Herb	TAHb	Anemochory
187 *Ewartia nubigena*	Silver Ewartia	Mat/Subshrub	FMa, TAHa	Anemochory
188 *Helichrysum scorpioides*	Button Everlasting	Herb	TAHa	Anemochory
189 *Lagenophora stipitata*	Blue Bottle-daisy	Herb	STG, TAHa	Anemochory
190 *Leptorhynchos squamatus* s.l.	Scaly Buttons	Herb	STG, TAHa, FMa	Anemochory
191 *Leucochrysum albicans* subsp. *alpinum*	Alpine Sunray	Mat/Herb	TAHa, FMa	Anemochory
192 *Microseris lanceolata*	Native Dandelion	Herb	TAHa, STG	Anemochory
193 *Olearia algida*	Alpine Daisy-bush	Shrub	H	Anemochory
194 *Olearia phlogopappa* var. *flavescens*	Dusty Daisy-bush	Shrub	H	Anemochory
195 *Olearia phlogopappa* var. *subrepanda*	Dusty Daisy-bush	Shrub	H	Anemochory
196 *Ozothamnus alpinus*	Alpine Everlasting	Shrub	B, H	Anemochory
197 *Ozothamnus* sp. (aff. *hookeri*)	Kerosene Bush	Shrub	B, H	Anemochory
198 *Ozothamnus secundiflorus*	Cascade Everlasting	Shrub	H	Anemochory
199 *Parantennaria uniceps*	Snowpatch Daisy	Mat/Herb	SAH, STG, B	Anemochory
200 *Picris angustifolius* subsp. *merxmuelleri*	Mountain Picris	Herb	TAHa	Anemochory
201 *Podolepis robusta*	Alpine Podolepis	Herb	TAHa, STG	Anemochory
202 *Rhodanthe anthemoides*	Chamomile Sunray	Herb	TAHa	Anemochory
203 *Senecio gunnii*	Gunn's Groundsel	Herb	TAHa	Anemochory
204 *Senecio pinnatifolius* var. *pleiocephalus*	Highland Groundsel	Herb	TAHa, STG	Anemochory
205 *Senecio pectinatus* var. *major*	Alpine Groundsel	Herb	TAHa, FMa	Anemochory

Appendix 2. Introduced species well established in the Kosciuszko alpine area. Taxa from Costin *et al.* (2000).

Species	Common Name	Probable Dispersal Agent
Poaceae		
Agrostis capillaris	Brown-top Bent	Anemochory
Dactylis glomerata	Cocksfoot	Anemochory
Festuca rubra	Red Fescue	Anemochory
Phleum pratense	Timothy Grass	Zoochory
Poa annua	Annual Meadow-grass	Anemochory
Poa pratensis	Kentucky Blue-grass	Anemochory
Caryophyllaceae		
Cerastium vulgare (syn. *Cerastium fontanum* subsp. *trivale*)	Common Mouse-ear Chickweed	Anemochory
Spergularia rubra	Red Sand-spurrey	Anemochory
Polygonaceae		
Acetosella vulgaris (syn. *Rumex acetosella*)	Sheep Sorrell	Anemochory
Fabaceae		
Trifolium ambiguum	Pellet Clover	Anemochory
Trifolium repens	White Clover	Anemochory
Asteraceae		
Achillea millefolium	Milfoil, Yarrow	Anemochory
Hypochoeris radicata	Cat's-ear	Anemochory
Taraxacum officinale sp. agg.	Dandelion	Anemochory

One Hundred Years Ago

On The Fertilization of Phanerogams

I.—Dispersion of Pollen by the Wind.

By G. Weindorfer

(*Read before the Field Naturalists' Club of Victoria*, 13*th July*, 1902.)

For the conveyance of pollen between flowers there exist two main agents, viz., the wind and insects. Phanerogamous plants have been separated by botanists into "anemophilæ," or wind-fertilized, and "entomophilæ," or insect-fertilised plants.

As would be naturally expected, it is, speaking generally, only pollen of a dusty consistency which is transported by the wind; but the pollen of some flowers is occasionally torn away from the anthers, in the form of sticky masses, and conveyed to the stigmas of neighbouring flowers by the wind, but the occurrence can only be looked upon as accidental, and would happen in the rarest instances. Still more remarkable is the fact that in certain water plants the pollen, though cohering in sticky masses, is blown by the wind in a kind of little boat to the stigmas, which are raised above the surface of the water.

From *The Victorian Naturalist* **XIX**, p 98, November 6, 1902

Vale

Club Members will be saddened to learn of the recent death of the following members:

Natalie Smith in July
Elsie Costermans in August
Eric Allen in September

Each made a great contribution to natural history and individual tributes will appear in later issues.

The Red Fox *Vulpes vulpes* L. in the Dandenong Creek Valley: Impacts on Wildlife and an Integrated Program for their Control

A Morton[1], D Tagg[1], R Wallis[2] and J White[1]

Abstract

Foxes in the Dandenong Creek Valley were found to consume many native vertebrate species, including three mammals, thirteen birds and at least one lizard. As well, foxes spread weeds by dispersing viable Blackberry seeds in their scats. A Co-ordinated Fox Control Committee representing eight landholders in the study site oversees the continuing project on land which includes many parks, four golf courses, a freeway easement, a water retarding basin, a quarry, two waste transfer stations and small blocks used for agriculture and stock agistment. Recommended control methods include den fumigation and removal of diurnal weed shelter. (*The Victorian Naturalist* **119** (6), 2002, 269-275)

Introduction

The Red Fox *Vulpes vulpes* L. is an introduced canid predator that is now widespread across the southern half of the Australian continent. Fox predation is considered a major threat to the conservation of native Australian fauna, especially ground nesting birds and those mammals in the critical weight range of between 35 and 5500 g (Burbidge and McKenzie 1989; Saunders *et al.* 1995). Predation by foxes is listed as a key threatening process under both Federal and Victorian Government legislation and appropriate plans have been devised to address the threat to wildlife (Mansergh and Marks 1993; Environment Australia 1999). Foxes can also be serious pests in agricultural areas, preying heavily on lambs and poultry in particular and are a potential vector for the transmission of rabies (Saunders *et al.* 1995).

Foxes are opportunistic in their diet, taking a variety of vertebrates, insects and vegetation. A number of dietary studies have been conducted in rural Australia in both forested and agricultural settings (see Brunner and Wallis 1986), but there have only been a few reports published on fox diet (Wallis *et al.* 1996) or on fox densities in urban environments in Australia (Marks and Bloomfield 1999).

In this report we describe a co-ordinated fox control program conducted by eight land manager/landholder groups in the Dandenong Creek Valley in Melbourne's eastern suburbs. The program relied on the establishment of a committee that oversaw a study into the diet, habitat use and control of foxes conducted by staff and students from Deakin University's School of Ecology and Environment. We also report on 'pre-control' data gathered to date in this four-year program and an outline of planned future activities.

Methods

Study site

The study site in the Dandenong Creek Valley is approximately 13 km long and 1-3 km wide. Situated in Melbourne's eastern suburbs, it extends from north of Boronia Road, Wantirna, to Stud Road, Rowville, in the south (Fig. 1). Dandenong Valley Parklands, managed by Parks Victoria, forms the largest portion of the study site and combines 1325 ha of popular recreation and parkland settings with conservation areas and farmland. Managed parks include Koomba Park, Bushy Park Wetlands, Nortons Park, Shepherds Bush, the Linear Trail, Jells Park and Chesterfield Farm.

Other agencies that manage land in the study site and are members of the Co-ordinated Fox Control Committee are the Cities of Monash, Knox and Whitehorse, Vic Roads (easement of the Scoresby Freeway), Melbourne Water (Winton Wetlands north of Boronia Road and the Police Road Retarding Basin between Wellington Road and Stud Road), Boral Bricks (which manages a quarry and a farmland) and Kingston Links Golf Course. The study site includes four golf courses: Kingston Links, Tirhatuan, Waverley Municipal and

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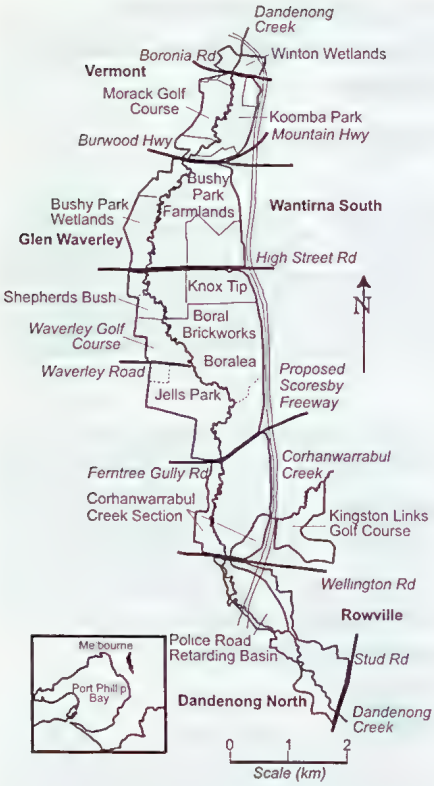

Fig. 1. Dandenong Creek Valley forms the border between the municipalities of Whitehourse and Monash to the west and Knox to the east.

Morack. Two waste transfer stations are present and large blocks of Parks Victoria, Vic Roads and Melbourne Water land are used for horse agistment, cattle grazing and fruit and flower growing. We believe such co-operation between all landholders in fox control in a semi-urban setting is unique and a necessary condition if successful management of foxes is to be achieved.

The study area is fringed on all sides by residential and factory development and some open land. Dandenong Creek has been severely modified over time and is prone to heavy flooding up to three times per year.

Study design and methods

The project began in 1998. In the first two years the aims were to:

- describe the diet of foxes in the area to determine the effects on wildlife;
- describe the potential for foxes to spread Blackberry *Rubus fruticosus* spp. agg. via seed germination from their scats;
- survey for sites of weed harbour suitable as refuge for foxes;
- survey the site for foxes and dens;
- review methods suitable for urban environments for the control of foxes.

Fox scats were collected weekly from January 1998 till January 1999 from Koomba Park and Boral Bricks sites. As well, less frequent, opportunistic collecting occurred over this period elsewhere, with monthly collections from transects established in the Police Road Retarding Basin, Corhanwarrabul Section, Jells Park, Shepherds Bush, Bushy Park Wetlands, Morack Golf Course, Kingston Links Golf Course and Drummies Bridge Reserve (Fig. 1). Scats were identified by size and shape (Triggs 1996), collected in manila envelopes, sterilised, washed, sorted and the food items identified and categorised using techniques described in Brunner and Wallis (1986) and Wilson and Wolrige (2000). Feathers found in the scats (and in den litter) were identified against specimens held at the Bird Observers Club of Australia premises; mammal bones were identified using specimens at Deakin University.

Fox scats containing Blackberry seeds were collected over a 6-week period during February and March 1998. They were washed in water with a 10% solution of commercial fungicide to inhibit fungal growth. Blackberry seeds were placed onto filter paper in petrie dishes and kept in a germination cabinet at 18°C over a 9-month period, where they were kept moist and monitored for seedling development. Some of these seeds were kept at 25°C for a period. Another group of seeds was first treated at 0°C and 4°C for a 3-week period before being placed into the germination cabinet at 18°C.

Approximately half of the seeds were tested for viability using tetrazolium chloride. Tetrazolium salts are used to indicate the presence of dehydrogenase enzymes, which provide reduction processes in living tissue. Dehydrogenase enzymes reduce tetrazolium salts to red or blue substances which appear as stains on viable seeds. Dead tissues remain unstained as there are no active enzymes present (MacKay 1972). The Blackberry seeds were placed in a 0.1% tetrazolium chloride and buffer solution at neutral pH and the number of

stained seeds counted to estimate viability. In December 1998 the remaining seeds (those not used in viability testing) were placed into potting mix in four pots which were exposed to normal sunlight and rain. There was no additional watering.

In April 1998 six scats containing Blackberry seeds were planted directly into potting mix. Fifty seeds from four of these were washed in a 10% fungicide solution and individually placed in the potting mix. The other two scats were not treated, but were planted whole into the pot. The pots were then placed in a glasshouse where they received regular watering and monitoring.

The public was kept informed about the project through frequent articles in the local press and talks to local resident groups. As well, 1200 flyers were distributed to households around the study site which sought reports from residents seeing foxes – people were invited to phone a 'fox hotline' at the university.

Each management section was systematically searched for den sites. Dens were classified as active if foxes were actually observed using them, if there were obvious signs of fox prints in freshly raked sand placed near the entrances or if there was den litter nearby (Coman 1972). The presence of scats and flattened grass around a den also provide good evidence of activity (Macdonald 1987). Dens and weed harbour patches were mapped using a GPS; volunteers, Green Corps personnel, student classes and Parks Victoria staff all assisted in these tasks.

The recommendation of appropriate control measures for each of the eight organisations was an aim of this research. These recommendations took into account current legislation, community concerns and the safety of domestic animals. Fumigation of den sites using Denco-fume carbon monoxide cartridges was selected as the most humane and species-specific method of control in an urban environment.

Results and Discussion

Diet studies

A total of 719 scats was collected from seven areas. Bones were the most frequently detected food item (56% of all fox scats examined contained bones). These included bones of mammalian and avian prey as well as those which probably came from garbage. Hair was found in 40% of scats. Other frequently found items included invertebrate (mainly insect) remains (55%), plant material (non-seed) (53%), seeds (41%) and feathers (28%). Of the 298 scats with seeds, 168 had Blackberry, all of which were found in summer/early autumn. Most invertebrate remains detected in scats were collected in spring, summer and autumn. On the other hand, feathers occurred in roughly similar percentage frequencies in all seasons.

Table 1. Occurrence of specific mammals in 219 fox scats containing hair collected over one year from seven major locations in the Dandenong Valley Parklands and surrounding sites. Percentages in parentheses. * denotes introduced species. Fox grooming hairs ignored.

Species	Number of occurrences
European Rabbit/Brown Hare *Oryctolagus cuniculus/ Lepus europaeus**	83 (29)
Common Ringtail Possum *Pseudocheirus peregrinus*	71 (24)
Black Rat *Rattus rattus**	56 (19)
Common Brushtail Possum *Trichosurus vulpecula*	40 (14)
House Mouse *Mus domesticus**	34 (12)
Brown Rat *Rattus norvegicus**	10 (3)
Sheep *Ovis aries**	4 (1)
Sugar Glider *Petaurus breviceps*	3 (1)
Cattle *Bos taurus**	2 (<1)
Cat *Felis catus**	1 (<1)
Total scats with hair	**291**

Table 1 shows the European Rabbit *Oryctolagus cuniculus* as the preferred food item followed by the Common Ringtail Possum *Pseudocheirus peregrinus*. Three scats contained the remains of the locally rare Sugar Glider *Petaurus breviceps*. Remains of birds were found in 204 scats and 17 species of birds were identified from their feathers (Table 2). Four of these species were also found as den litter.

Foxes in the Dandenong Creek Valley were shown to consume a wide variety of prey. Mammals, birds and invertebrates (chiefly insects) are taken together with seeds such as Blackberry and fruit. Whilst rabbits, rats and mice appear frequently in fox scats, three native mammal species are eaten. The appearance of Sugar Glider remains in fox scats, whilst rare, is of

Table 2. Bird species taken as prey by foxes in the study area. Feathers found in fox scats were compared with those from specimens. # indicates species also found as 'den litter' around a natal den in Jells Park between September and November 1998. * denotes an introduced species.

Scientific name	Common name
Threskiornis molucca	Australian White Ibis
Porphyrio porphyrio#	Purple Swamphen
Chenonetta jubata	Australian Wood Duck
Anas superciliosa	Pacific Black Duck
Larus novaehollandiae	Silver Gull
Gallirallus philippensis	Buff-banded Rail
Cacatua galerita	Sulphur-crested Cockatoo
Platycercus eximius#	Eastern Rosella
Trichoglossus haematodus	Rainbow Lorikeet
Accipiter fasciatus	Brown Goshawk
Grallina cyanoleuca	Magpie-lark
Gymnorhina tibicen#	Australian Magpie
Corvus mellori	Little Raven
*Streptopelia chinensis**	Spotted Turtle-Dove
*Acridotheres tristis**	Common Myna
*Sturnus vulgaris**	Common Starling
Turdus merula#*	Common Blackbird

concern. This species is highly vulnerable to predation by cats and foxes and its distribution in urban areas is rapidly declining (Brunner *et al.* 1991). Dandenong Valley Parklands is one of the closest sites to Melbourne inhabited by Sugar Gliders.

Scats collected from different sites in the study area had different proportions of prey. For example, hair from Sugar Gliders was only found in scats collected from Koomba Park, while scats from Boral Quarry had higher numbers of feathers and bones than other areas. Although these feathers were not identified, both Boral Quarry and the proximate Knox Tip supported wetland bird populations. A large population of scavenger birds including Silver Gull *Larus novaehollandiae* and Australian White Ibis *Threskiornis molucca* was present at the Tip. Many of the bone fragments were from domestic rubbish accessible to foxes at the open landfill site of Knox Tip.

Rabbits and Brown Hares *Lepus europaeus* were common in fox scats collected at Boral and the Police Road Retarding Basin. Our data are similar to those reported in Wallis *et al.* (1996) for fox scats collected in 1989 and 1990, although the proportion of scats containing the remains of rabbits has increased significantly.

As well, foxes are likely to prey on frogs and lizards – one Blue-tongued Lizard *Tiliqua* sp. was found with its skin removed beside the entrance of a fox natal den. Wallis *et al.* 1990 reported that Dandenong Valley Parklands represents a linear reserve of modified bushland in a 'sea' of suburbia providing largely unsuitable habitat for sustainable wildlife communities. They compared the diet of foxes, dogs and cats in the Dandenong Valley Parklands and from the evidence found that predation by these three introduced species threatened the continued survival of some native vertebrates in the Parklands.

Germination trials

Those seeds tested for viability with tetrazolium chloride showed a positive response with 120 of 391 seeds (or 31%) showing viability. However, there was no germination from seeds whilst in the germination cabinet. In December 1998 the remaining seeds were planted into potting mix. In August 1999 these seeds germinated with 166 seedlings growing from a total of 660 seeds, a germination rate of 25%, 18 months after being deposited by the foxes (Table 3).

In comparison, the scats that were planted directly into potting mix in March 1998 germinated in August 1998 just five months after deposit. The scats planted whole germinated at a much faster rate than the individual seeds. Of 50 individual seeds planted into each of four pots only 29 germinated – a maximum of 15% germination. Growth was uneven with one pot yielding 32%, but the others only 12%, although seedling growth in all four was strong and vigorous. In the other two pots planted with whole scats, many more seedlings germinated – 32 and >50 – but as the number of seeds planted were not counted no germination rate could be calculated. Many of these seedlings were still present in 1999 although growth was limited by the lack of resources in the pot. Once these seedlings were removed more seedlings germinated in August 2000. One whole scat planting had 43 new seedlings present.

We have demonstrated that Blackberry seeds in fox scats are viable and capable of

Table 3. Treatments of various groups of Blackberry seeds collected in fox scats during February/March 1998. GC, germination cabinet; R/F, refrigerator/freezer.

	Group A	Group B	Group C	Group D	Group E
Date collected	Feb/Mar '98	Feb/Mar '98	Feb/Mar '98	Feb/Mar '98	Mar '98
1st treatment	GC at 18°C	GC at 18°C	GC at 18°C	R/F 3 weeks	-
2nd treatment	-	Tested for viability Jul '98	GC at 25°C Aug/Sep '98	GC at 18°C	-
Planted	Dec '98	Dec '98	Dec '98	Dec '98	Mar '98
Germination	Aug '99	Aug '99	Aug '99	Aug '99	Aug '98, Aug '00

germination. Fox scats may contain more than 50 seeds, which remain viable for at least two years in storage and pots. Since foxes may travel up to 10 km per night (Saunders *et al.* 1995), there is potential for widespread dispersal of Blackberry throughout this area. Blackberries may have a laxative effect on foxes as there are many more scats collected during the Blackberry fruiting season than at other times of the year. Blackberries provide an easy resource for foxes and require minimal energy expenditure to harvest them.

Blackberry appears to benefit from dispersal by foxes. The whole scats planted in potting mix without other treatment produced higher germination rates than for seeds that were washed in fungicide. Seeds from the germination cabinet showed no germination until they were planted into potting mix, while none of the seeds, from the germination cabinet or direct sowing, germinated before late August. This may indicate that the length of daylight provides the trigger for growth. The nutrient package provided by the fox may also improve the number of seeds germinating.

Brunner *et al.* (1976) collected Blackberry seeds from scats of foxes and found germination did not commence until early Spring, some six months after they had been collected. Overall they found germination rates of between 22% and 35%. Our conclusions concur with those of Brunner *et al.* (1976) and Amor and Richardson (1980) who concluded that foxes are a major dispersal agent for Blackberry in Victoria, particularly in sites which are prone to flooding after heavy rainfall.

Weed mapping

The presence of Blackberry, Gorse *Ulex europeaus* and Wandering Tradescantia *Tradescantia fluminensis* was mapped and the maps used by land managers to control infestations. Other weeds were also mapped if it was thought they were in such high densities that they might provide cover for foxes. Many organisations involved have since carried out weed control and in some places have followed with landscaping and revegetation programs. These and other weeds found are declared noxious weeds and pest plants in the study area (Knox City Council and Maroondah City Council 1999).

Fox Hotline

Some 46 people telephoned the 'Fox Hotline' reporting sightings, although some were for foxes seen outside the study area. Interestingly, a number expressed concern for the safety of their own pets, including aviary birds, from fox predation. Others were concerned with the noise made by foxes.

Density estimate

Marks and Bloomfield (1999) used natal den counts to estimate family group density in Melbourne's suburbs. They found foxes living, and in many cases breeding, in all parks larger than 20 ha within 10 km of the GPO. Foxes were especially common in parkland associated with creeks and rivers. Our study site was most similar to their Box Hill/Camberwell site in terms of housing, parkland and presence of thick vegetation and weed infestations used by foxes for diurnal shelter. An average of 1.13 independent active natal dens/km^2 with a mean distance to the nearest neighbour of 1.09 km was found in that area. The natal dens in our study area were distributed in a similar fashion. Furthermore, Marks and Bloomfield (1999) found a mean of 4.36 cubs produced per den, a figure which is comparable to urban den litter sizes recorded for foxes elsewhere (Harris and Smith 1987). Typically in Australia the predomi-

nant social group consists of an adult breeding pair and cubs with perhaps one or two non-breeding vixens (often young of previous litters). However, in sites that have high resource availability (food and shelter), workers have observed polygamous social groups (Macdonald 1979) or tolerance of the presence of non-breeding males (both itinerant and non-dispersing) (Lovari *et al.* 1994).

Using these numbers and an area of 16.5 km^2 it is reasonable to estimate that there may be approximately 80 foxes living in the study area. Given the observations mentioned in overseas studies this may be a conservative estimate with numbers variable across the year.

Fox control

There are few options available in urban areas for fox control. The poison 1080 (monosodium fluoroacetate) is one of the most selective and safe means of fox control and has been used successfully in Western Australia where native species have a higher tolerance to the poison (McIlroy 1986; King and Kinnear 1991). Fox poisoning has been especially successful when baits have been buried in bait stations (Saunders *et al.* 1995). Poisons like 1080 and cyanide cannot be used in urban sites because of the risk to non-target species at bait stations or cache sites. Foxes are known to cache food and might carry a bait up to 800 m before caching it. Domestic dogs could be at risk if a fox were to cache a bait in a residential area (Kay *et al.* 1997).

Similarly, shooting was ruled out because of the dangers involved in using firearms in built-up areas. Trapping with soft-jawed traps is an inefficient means of fox control (Saunders *et al.* 1995; Kay *et al.* 2000). The only practicable method for fox control in the Dandenong Valley Parklands and surrounding sites was for natal den fumigation and destruction and removal of weed harbour used as cover by foxes.

To date, 33 fox dens have been located, although not all were being used in the study period. Five were used as natal dens, whilst six others showed signs of recent use. Family groups tended to use multiple dens and den sites were regularly dispersed throughout the study site. Many dens were found under the cover of weeds such as Blackberry, Gorse and Wandering Tradescantia. Other dens were found in mounds in the open with introduced grass cover, under trees with introduced or natural grass cover, in drains or dug into dam walls (with or without overstorey cover). The most common factor for den sites was the use of a mound or earth wall which provided easy digging for the fox.

A professional pest controller was engaged to supervise den fumigation and a total of 29 of the 33 possible sites was checked by his dogs. Nine sites were selected for fumigation from the amount of interest shown in the den by the dogs. Two other sites were unable to be fumigated due to the complete Blackberry cover.

Two weeks later, three fumigated sites were opened by a backhoe to assess the success of the control exercise. Two sites had been reopened by foxes since the fumigation, one of which was still in use as a natal den. One cub was dispatched at this site. Six other sites were unable to be backhoed due to the nature of the surrounding vegetation or terrain. Three of these were in sensitive remnant vegetation or were dug into dam walls. There was no access for the backhoe at the final three sites.

Fumigation is neither as cost-effective nor as efficient as 1080 baiting. Locating fox dens is labour-intensive and time-consuming and fumigation must be carried out within the first eight weeks after the birth of the cubs. After this time both vixen and cubs leave the den. The dog fox and any sub-dominant females do not use the den but may support the vixen and cubs with the supply of food (Macdonald 1979). At best, fumigation will remove only one generation of foxes, whilst leaving other adult foxes to continue the attack on native mammals and birds.

This study has shown that foxes will reopen den sites that have been closed for fumigation if the site is not levelled with a backhoe. Unfortunately, not all sites are accessible to a backhoe as they were located in important remnant vegetation. These sites are then available for reuse by foxes.

Although studies indicate that fumigation may reduce predation by 92% (Hewson 1986) this would assume that no new foxes could inhabit the area. Marks and Bloomfield (1999) have estimated that there may be as many as 16 foxes/km^2 in residential areas. Once an area becomes

vacant due the effects of a fox control program there will be immigration from areas of greater fox density. For these reasons fumigation cannot be considered by itself as a successful method of fox control.

The manipulation of habitat might become the means of keeping fox numbers to a minimum in the Dandenong Creek Valley. This would necessitate the removal of Blackberry and Gorse, which provide food and harbour resources for foxes, and some of their favoured prey species, rabbits and rodents. Blackberry also provides harbour for these prey; the removal of Blackberry and other weed species would support a program of fox control and aid in the removal of rabbits and rodents. A continuation of this study will consider what effect habitat manipulation will have on the success rate of a control program.

The next stage

Follow-up fox surveys will be carried out in the next phase of the project after weed harbour and den destruction. As well, we will continue to collect and process fox scats to monitor change in diet over the seasons. The Co-ordinated Fox Control Committee which oversees the project was recently successful in receiving funding from the Natural Heritage Trust to compare fox behaviour, use of daytime habitat and home range in sites where weed harbour has been removed with a control site. We hope this will provide insights into how fox activity and movements change in response to habitat modification.

Acknowledgements

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Flying Spiders and Crawling Flies

December has come and the new year is fast approaching; with summer settling in it tends to be a quiet time in the mountains for the bigger wildlife. The birds have settled down, most of the migratory birds having arrived in the mountains for the summer in September or October; breeding is past the raucous courtship phase and parents are busy feeding their young. Even the Crescent Honeyeaters *Phylidonyris pyrrhoptera* have quietened down.

The small mammals, Dusky and Agile Antechinus *Antechinus swainsonii* and *A. agilis*, and Mountain Pygmy Possum *Burramys parvus*, are carrying pouch young. The female antechinuses are hard to catch, while the males are long gone, and at higher altitudes the young are difficult to catch until some time into February. The Bogong Moths *Agrotis infusa* are in their aestivation sites and not going anywhere in a hurry. At this time the flowering plants have it all their own way with the tourists, while the more obvious insects in your field of view tend to be the pollinators: butterflies, wasps and bees.

But summer days drift on by to the sounds of everyone's least favourite, flies: March Flies, bushflies, blowflies, mosquitoes and the knuckle-biting black flies – these are the ones that grab all the attention. Out of the limelight of the tourist-packed Main Range with its multitude of flowering plants and butterflies, other animals are equally busy.

Everywhere spiders and flies are creeping. Creeping flies? The Soldier Fly *Boreoides subulatus* (Stratiomyidae) is one of the insects most commonly brought to entomologists for identification and one which people only have to begin describing at this time of year for me immediately to know what they are talking about. This strange looking fly, in which the wingless female is many times the size of the male, looks vaguely threatening. Not so vaguely to some, who think they have been attacked by one when it tumbles out of a tree on top of them. At the lower altitudes of Canberra, there is a spring and an autumn brood, whereas in the snow-country *Boreoides* has just one breeding season per year. The female emerges already gravid and is mated by more than one of the winged males. After mating, the females climb – up a post, a tree, a tent pole, it doesn't matter – looking for a hole in which to lay their eggs. They can be found with ovipositor buried in a hole carved out by beetle or moth larvae. The female does no digging herself but in some holes half of her body might disappear from view. Any hole will do. I have had them lay eggs in a fence post at home or in the apex of my tent way back when I had an A-frame tent. The female seems to lay all her eggs in the one hole; certainly she lays a lot. The young will later descend to live in the soil.

Also creeping at this time (and the reason that years ago I went off the A-frame tent without the floor), are male Funnelwebs, one of the two still-undescribed species of *Hadronyche* (Hexathelidae) found in the mountains. It is at about this time that the males go in search of the females, who remain in their holes or beneath an exfoliating slab of granite. For most people, the evidence won't be there until January when bodies of male Funnelwebs litter the alpine grassland. But at night the grasslands abound in them, to the extent that going out of the tent in bare feet in December can be a nerve-racking activity. For me it was at night in my floorless tent, with a Funnelweb glistening by candlelight on my pillow beside me as I read my book. A torch-lit search outside revealed another 13 males within a couple of metres of the tent. A tent with sewn-in floor was purchased soon after! The density is astounding, and the holiday season is the time when a number of bites (none yet fatal) occur.

I have recorded flies among a horde of insects, moths, and wasps migrating across Dead Horse Gap (a Mecca for anyone interested in migration of birds or insects; see Green 1982), but spiders also migrate. On summer days the gossamer threads, 2-3 m long, of spiders floating through the air can be seen against the sun. Young spiders use this technique, called ballooning, for dispersal from nest sites. When ready for migration, the abdomen is raised and silk extruded, drying and being caught by the wind which finally lifts the spiderling from the ground, sometimes to heights in excess of 4000 m. The lines of silk on the ground are often the results of failed take-off attempts. Malaise traps (normally set to catch flying insects) set in the alpine zone between the top of the Thredbo chairlifts and Mt Kosciuszko during the 'Biodiversity Blitz'

in January this year (Green 2002) collected over 100 such dispersing juvenile spiders. About 90% of the specimens collected in the malaise traps were thomisids (Thomisidae), comprising what appears to be two species of *Diaea*. Despite all this gossamer, aerial web building spiders are uncommon in the mountains in comparison to lower altitudes. The short summer season, strong winds and snow probably make the capture of aerial food with a web a little problematic, and most spiders rely on terrestrial hunting. But spiders have no difficulty getting to the mountains or even being some of the earliest colonisers of new mountains or newly exposed parts of old mountains, as snow and glaciers retreat. Ballooning is their major mode of transport and they are able to exist even above the limit of plant growth. This is what is called the aeolian zone, where life forms exist on the material brought in by the wind (a fairly obvious phenomenon from the Snowy Mountains to Canberra in October this year when a fair bit of the cropland out west came visiting). At times, on high mountains, spiders may be the only life form present (except man). Leslie Stephen wrote in 1874 'The only creature besides myself that could fairly be called living was a small black spider, which had been led by an apparently misguided spirit of enterprise to seek for prey in this loftiest zone of organic existence' (*A Bye Day in the Alps*).

Of the nearly 70 families of spiders found in Australia, only 27 have been recorded above the winter snowline (1500 m) in the Snowy Mountains, and 20 of those are only known from one or two species (Green in press). The best known are the Lycosidae (Wolf Spiders) where half of the eight known species have been described. In the herbfields and grasslands, burrows of Wolf Spiders are common, and you can sometimes find a burrow every one or two square metres. In December, the female Wolf Spiders sit at the entrance to their web-covered burrow, holding on to their egg case – scuttling back inside when danger arrives. Later in the summer they can be seen with young on their backs. Sometimes when you disturb them on a sunny day you can see hundreds of spiderlings scuttling back to their natal burrow on your approach.

One thing that constantly keeps me on my toes in the mountains is the appearance of the unusual among the mundane. Bogong Moths are well known for their gregarious aestivation in cracks among the rock tors and blockstreams. During my studies of the moths and associated arsenic last year (Green *et al.* 2001) I found the relative humidity in a bogong moth site over summer averaged around 75% with the average air temperature below 8°C. These cool damp conditions also attract blowflies, ever-present in the snow-country – even in winter – and small flies. These join the giant springtails and other detritivores crawling around on the Bogong Moth debris on the floors of caves. All this (apart from the arsenic) was expected, but as I checked a cave on one hot day I found a particularly fuzzy rock. On closer examination it was covered in hundreds, maybe thousands, of small flies, lined up side by side, end to end, just like Bogong Moths. These turned out to be Fungus Gnats *Exechia* sp. (Mycetophilidae) which are often associated with damp places, including caves, as are their relatives the glow worms. Were these Fungus Gnats just taking advantage of the cool moist environment to avoid the dessicating effects of altitude and alpine sun? Or, like the two species of parasitic nematodes *Amphimermis bogongae* and *Hexamermis cavicola* (Mermithidae) that do not depart with their host moths but await their return each year, do the Fungus Gnats have an organic connection with the caves? Are they also dependent upon the annual cycle of Bogong Moth migration, death, decay and fungal growth? These are the sorts of questions that face the naturalist in our mountains, and yet another good reason for me to spend the summer sticking my head into any cave big enough to admit me.

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Grassed Up: Guidelines for Revegetating with Australian Native Grasses

by Cathy Waters, Wal Whalley and Charles Huxtable

Publisher: *NSW Agriculture, 2001. 72 pages, black and white illustrations. RRP $33.00*

The status of grasslands has been largely overshadowed in recent times by the environmental focus on planting trees, and more recently the inclusion of shrubs. Native grasses have generally been forgotten in the revegetation process, primarily because information on harvesting, dormancy and establishment has been scarce. Over the last few years, however, there has been a growing interest in native grasses in terms of pasture management and their environmental values, and consequently there has been a shift in emphasis from trees and shrubs to native vegetation as a whole. Landowners and land managers are now becoming aware of the role native grasses can play in rehabilitation of sites and are desperate for information on harvesting and establishment techniques for native grasses. *Grassed Up: Guidelines for Revegetating with Australian Native Grasses* is the first of such information. It provides practical advice with step by step instructions on native grass collection and establishment.

The *Guidelines* is an A4, 72 page spiral-bound booklet which the authors have divided into two easy-to-read sections. The first section provides general information on native grasses (chapter 1) and up to date techniques on collection (chapter 2), storage (chapter 4) and establishment (chapter 5). Whilst individual species' responses to fertilisers are covered generally in section two under individual species information, I would have liked to see the authors discuss soil fertility in more detail and the likelihood of increased weed competition under higher soil fertility.

Throughout the *Guidlelines* the authors have included a number of black and white photos to complement the text. The photos of the current machinery being used and diagrams of how they work are invaluable.

The second section contains details on fourteen native grass species considered to have a high priority for commercial development or those that are already being used in revegetation. Each information sheet is complete with photos and a description with information on morphology, distribution, harvesting, sowing and management. Whilst a lot of information is still unknown for many species, it would have been worthwhile for the authors to include information sheets on other native grasses such as *Austrostipa* and *Poa* species, making it more applicable to sites outside of NSW.

Included in the back of the book is a series of guidelines produced by FloraBank which outlines the protocols for seed collection and storage. There is also a useful list of publications on grass identification, harvesting and germination.

Grassed Up: Guidelines for Revegetating with Australian Native Grasses is a well-written account of native grass revegetation techniques. It is aimed at landowners, land managers or anyone interested in the practical application of the establishment of native grasses in revegetation, regeneration or the rehabilitation of degraded sites.

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For assistance in preparing this issue, thanks to Kate Smith (desktop publishing), Ann Williamson (label printing) and Dorothy Mahler (administrative assistance).

Platypus: the Extraordinary Story of How a Curious Creature Baffled the World

by Ann Moyal

Publisher: *Allen & Unwin, 2001. 226 pages, hardback. RRP $29.95*

Today, scientists confidently classify the platypus and echidnas as monotremes: egg-laying, milk-producing, fur-clad mammals. Based mainly on fossil evidence, it is believed that the many attributes which distinguish monotremes from marsupials and placental mammals – including differences in the structure of the ear, backbone, limb girdles, brain and sex chromosomes – reflect the fact that monotremes have been evolving independently of other mammals for 100 million years or more.

Ann Moyal has produced a fascinating and meticulously researched account of how the platypus's place in nature has come to be defined, and how that process was interwoven with the rise of evolutionary theory. The story begins in 1798 when John Hunter, governor of the penal colony at Botany Bay, watched 'a Small Amphibious Animal of the mole kind' being speared by an aboriginal man near the Hawkesbury River. The animal's skin was preserved in a keg of spirits and sent (along with a wombat) to the Literary and Philosophical Society of Newcastle-upon-Tyne, which had recently honoured Hunter with a corresponding membership. Upon its arrival, the keg was collected by a woman servant, who was carrying the container on her head when the bottom gave way and soaked her with alcohol. Looking down, her distaste grew with the realisation that she had been carrying the remains of 'a strange creature, half bird, half beast, lying at her feet'.

The bemused reaction of George Shaw, the first professional zoologist to examine a platypus (a dried specimen arriving in England in 1799) was fundamentally the same as that of the servant. 'Of all the Mammalia yet known, it seems the most extraordinary in its conformation, exhibiting the perfect resemblance of the beak of a Duck engrafted on the head of a quadruped.' Suspecting that the specimen was a hoax, he carefully probed at the line where the bill joins the head, but could find no stitching or other evidence of forgery. The mystery only deepened when a British anatomist, Everard Home, applied himself to the task of dissecting preserved platypus organs. Home's studies revealed that the structure of the platypus bill was actually quite unlike that of a duck's beak. However, after examining the reproductive systems of males and females, he concluded that they differed in many respects from the accepted mammalian pattern – and most closely resembled the organs of lizards which hatch eggs internally.

Scientific consensus about whether or not the female platypus can produce milk was not reached for another three decades. Heated debate about the platypus's mode of reproduction – live-bearing or egg-laying – would not be resolved until 1884. As a research biologist, I particularly appreciated Moyal's description of the obstacles facing the most brilliant academic minds of the 19th century in discovering the truth about the platypus, including their apparently universal reluctance to countenance first-hand observations made by colonials.

Moyal devotes relatively few pages to platypus-related achievements in the 20th century, though some interesting material is presented, including a description of the mission undertaken by David Fleay to satisfy Winston Churchill's desire to see a live platypus midway through the Second World War.

The text is complemented handsomely by illustrations of early platypus paintings and portraits of the zoologists and natural historians who contributed to our knowledge of the species. I commend the book to anyone with an interest either in Australian fauna or the argumentative and all-too-human process by which scientists reach agreement on how nature functions.

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Working on Country: Contemporary Indigenous Management of Australia's Land and Coastal Regions

Edited by Richard Baker, Jocelyn Davies and Elspeth Young

Publisher: *Oxford University Press, 2001. xxiv + 351 pages, 27 figures, 5 tables. ISBN 0195512170. RRP $49.95*

One of the more significant changes over the past 20 years or so, in a range of field disciplines that focus on natural resources, has been the increasing involvement of Aboriginal people. It has taken too long to recognise the rights of indigenous peoples or to give respect to their knowledge systems, so that meaningful collaborations could occur. As this book illustrates, however, indigenous people now not only have input, but are directing projects in all parts of Australia. Indeed, the major part of this volume consists of reports of close collaborations between indigenous and non-indigenous people, working in situations that give accord to indigenous knowledge and experience. *Working on Country* is both a statement for the cause of cross cultural collaboration and a testament to its enormous value.

Of course, collaborations and joint projects of the kind reported in this volume do not happen easily or without attendant challenges. Aboriginal understandings and uses of local land and sea resources are often at odds with those of non-indigenous managers, administrators, and academics; issues relating to ownership of resources and appropriate access also need to be resolved. And as the editors of this book point out, even the concepts of 'work' and 'country' can have different meanings for different groups. The resolution of these issues is often a matter of protracted discussion but, if nothing else, such resolution and the resulting collaborations can be seen as points of reconciliation at a grass roots level.

This book is divided into four parts. In the first, headed 'Contemporary indigenous management', two summary chapters provide an overview of the prime issues within the field. These essays are followed by a series of case studies grouped in three thematic sections: 'Approaches to managing country', 'Sharing knowledge: tools and communication', and 'Negotiating management'. The first paper in each of these three parts, written by the editors, introduces the relevant issues.

The studies that are detailed in this book were undertaken in different contexts and for a variety of purposes, including the management of land and sea resource, biological surveys, and heritage studies. The chapters focus on locations in almost every state of Australia, the exception being Victoria, which barely receives a mention in the entire book. However, this omission should not be taken as an indication that Kooris and Gubbas (non-Indigenes) are not working together in Victoria. Although not represented in this volume, collaborations of not dissimilar kinds are certainly taking place here.

Working on Country works well as an introduction to the ways in which seemingly opposed perspectives can be reconciled. The book's breadth of coverage and the emphasis on non-technical language are aimed in the direction of a wide audience. Although they work in academic environments, the editors have maintained a style that is both easy to read and informative. An interesting aspect of the presentation is the use of 'boxes' providing detail on a wide range of related subjects. These are inset in many of the chapters, and could usefully be read on their own.

This book is an important contribution to the subject of resource management. It provides interesting insights into the nature of connections between indigenous population and land and should also help to dispel the myth of a monocultural indigenous population in Australia. For these reasons alone, it should be recommended reading.

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Gardening With Australian Rainforest Plants

by Ralph Bailey and Julie Lake

Publisher: *Bloomings Books, Melbourne. 2001. 144 pp, paperback. RRP $32.95*

There is considerable interest in Australian rainforest plants for their conservation as well as cultivation and they are certainly worthy of our attention.

Rainforests contain some of the world's richest biological systems. It is vital that we appreciate these natural habitats and do all we can to ensure the preservation of the rainforest areas we still have in Australia, and, indeed, in other areas of the world.

Ralph Bailey and Julie Lake, in *Gardening With Australian Rainforest Plants*, remind us that a staggering 95% of Australia's rainforests have been felled in the last 200 years.

We sometimes think of rainforest plants as being applicable only to tropical regions but rainforests extend right down the eastern coast of Australia to Tasmania, with some pockets of rainforest also in Western Australia and the Northern Territory.

The introductory chapter covers the various types of Australian rainforests including Monsoon rainforest; Lowland and Upland tropical rainforests; Lowland and Upland subtropical rainforests; Littoral rainforest, Warm temperate rainforest, Cool temperate rainforest and to make sure that absolutely nothing is missed there is a further heading of Other Rainforests.

Many rainforest species are very adaptable to cultivation and quite a number of plants from north-eastern Australia are adaptable to cultivation in cool temperate zones.

The book proceeds to dispel some of the common myths about rainforests and rainforest plants. These include the incorrect assumptions that rainforest plants are difficult to grow and don't have attractive flowers and that all rainforest trees are tall. The book also points out that rainforest plants do not necessarily need a lot of water.

Five chapters give detailed advice on planning and planting a rainforest garden and its subsequent care. Small gardens, courtyards and container cultivation are covered in separate sections.

Rainforests and rainforest gardens can be wildlife havens and the chapter on Wildlife in the Rainforest Garden covers this aspect in considerable detail. Birds, butterflies (including caterpillars), frogs, other pond life and lizards are all included together with fungi, lichens and mosses which are all an intrinsic part of the total ecology. Even unwanted creatures receive a mention and some helpful advice.

Edible rainforest plants and a section on propagating rainforest plants are included prior to the final chapter which gives detailed descriptions of one hundred favourite rainforest plants.

Gardening With Australian Rainforest Plants is illustrated throughout with clear colour photographs and there are also a number of helpful line drawings to complement the text.

There is a Bibliography and comprehensive Index to complete its usefulness.

Ralph Bailey is a landscape architect who has been involved with Australian plants for more than 30 years. He has written extensively on rainforest plants, bush tucker and ecologically sensitive design.

Julie Lake is a horticultural writer and consultant with a particular interest in Australian rainforest plants. An active member of the Society for Growing Australian Plants and the Horticultural Media Association, she is a regular contributor to several Australian magazines and lectures on rainforest plant identification.

Gardening With Australian Rainforest Plants is a very easy-to-use book which will show readers how to turn a garden into a cool, green haven, and to transform the landscape into something distinctively Australian.

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Guidelines for Authors – The Victorian Naturalist

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Authors may submit material in the form of research reports, contributions, naturalist notes, letters to the editor and book reviews. A ***Research Report*** is a succinct and original scientific paper written in the traditional format including abstract, introduction, methods, results and discussion. A ***Contribution*** may consist of reports, comments, observations, survey results, bibliographies or other material relating to natural history. The scope of a contribution is broad and little defined to encourage material on a wide range of topics and in a range of styles. This allows inclusion of material that makes a contribution to our knowledge of natural history but for which the traditional format of scientific papers is not appropriate. Research reports and contributions must be accompanied by an abstract of not more than 200 words. The ***abstract*** should state the scope of the work, give the principal findings and be complete enough for use by abstracting services. Research reports and contributions will be refereed by external referees. ***Naturalist Notes*** are generally short, personal accounts of observations made in the field by anyone with an interest in natural history. These may also include reports on excursions and talks, where appropriate, or comment on matters relating to natural history. ***Letters to the Editor*** must be no longer than 500 words. ***Book Reviews*** are usually commissioned, but the editors also welcome enquiries from potential reviewers.

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Leigh J, Boden R and Briggs J (1984) *Extinct and Endangered Plants of Australia*. (Macmillan: South Melbourne)

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Members receive *The Victorian Naturalist* and the monthly *Field Nat News* free. The Club organises several monthly meetings (free to all) and excursions (transport costs may be charged). Field work, including botany, mammal and invertebrate surveys, is being done at a number of locations in Victoria, and all members are encouraged to participate.

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